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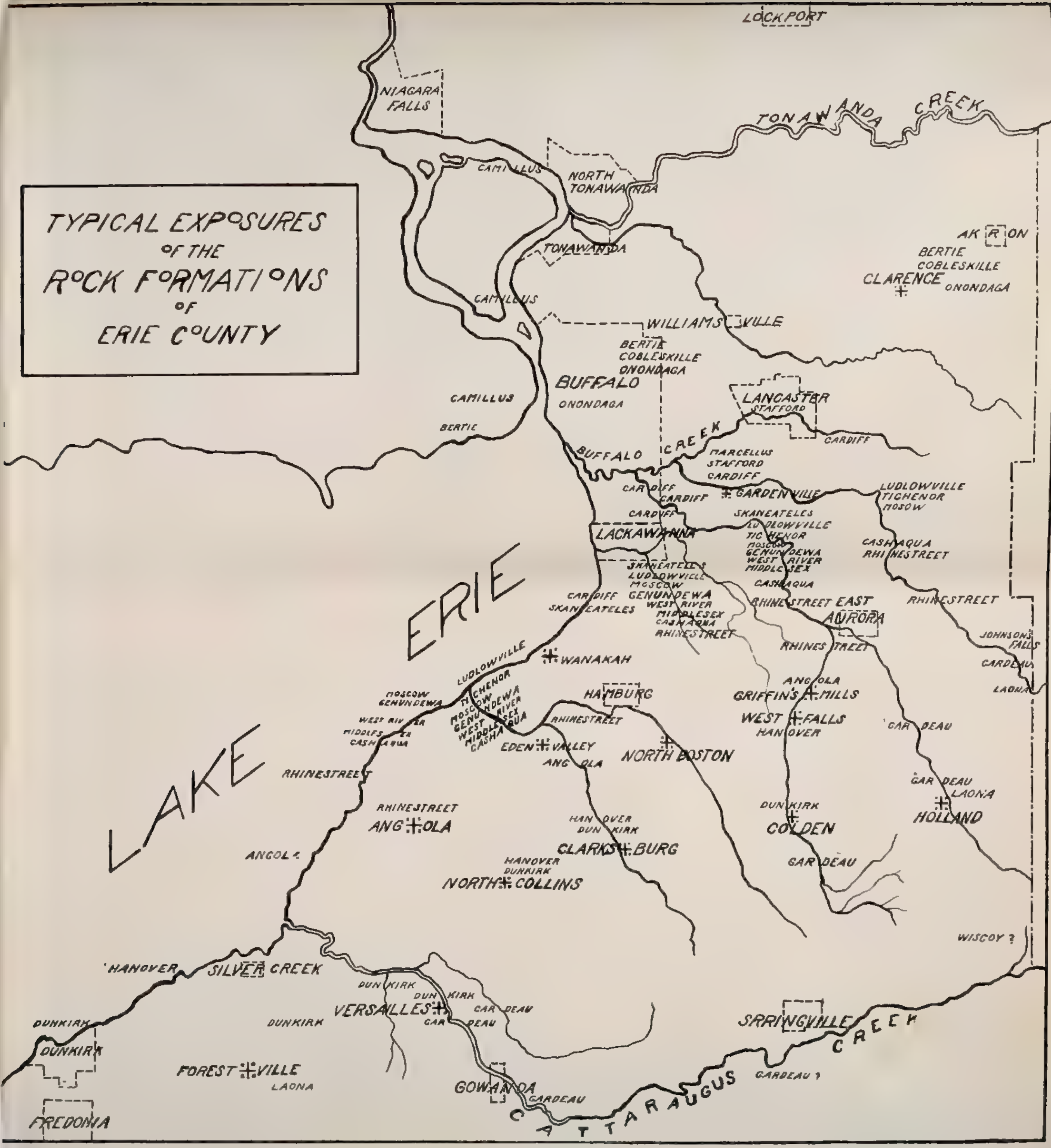

TYPICAL EXPOSURES OF THE ROCK FORMATIONS OF ERIE COUNTY

LOCKPORT
NIAGARA FALLS
TONAWANDA CREEK
CAMILLUS
NORTH TONAWANDA
TONAWANDA
AKRON
BERTIE
COBLESKILLE
CLARENCE
ONONDAGA
CAMILLUS
WILLIAMSVILLE
BERTIE
COBLESKILLE
ONONDAGA
BUFFALO
ONONDAGA
CAMILLUS
BERTIE
LANCASTER
STAFFORD
BUFFALO CREEK
CARDIFF
MARCELLUS
STAFFORD
CARDIFF
CARDIFF
CARDIFF
GARDENVILLE
LUDLOWVILLE
TICHENOR
MOSCOW
CARDIFF
SKANEATELES
LUDLOWVILLE
TICHENOR
MOSCOW
GENUNDEWA
WEST RIVER
MIDDLESEX
LACKAWANNA
CASHAQUA
RHINESTREET
SKANEATELES
LUDLOWVILLE
MOSCOW
GENUNDEWA
WEST RIVER
MIDDLESEX
CASHAQUA
RHINESTREET
CASHAQUA
CARDIFF
SKANEATELES
RHINESTREET
EAST AURORA
RHINESTREET
LAKE ERIE
RHINESTREET
JOHNSONS FALLS
GARDEAU
LAONA
WANAKAH
LUDLOWVILLE
TICHENOR
MOSCOW
GENUNDEWA
WEST RIVER
MIDDLESEX
CASHAQUA
MOSCOW
GENUNDEWA
WEST RIVER
MIDDLESEX
CASHAQUA
HAMBURG
RHINESTREET
ANGOLA
GRIFFIN'S MILLS
WEST FALLS
HANOVER
GARDEAU
EDEN VALLEY
ANGOLA
NORTH BOSTON
RHINESTREET
GARDEAU
LAONA
HOLLAND
RHINESTREET
ANGOLA
DUNKIRK
COLDEN
HANOVER
DUNKIRK
CLARKSBURG
ANGOLA
GARDEAU
HANOVER
DUNKIRK
NORTH COLLINS
WISCOY ?
HANOVER
SILVER CREEK
DUNKIRK
DUNKIRK
GARDEAU
VERSAILLES
GARDEAU
SPRINGVILLE
DUNKIRK
DUNKIRK
DUNKIRK
FORESTVILLE
LAONA
GOWANDA
GARDEAU
CATTARAUGUS CREEK
GARDEAU ?
FREDONIA

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BULLETIN

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Buffalo Society of Natural Sciences

VOLUME XI. No. 1

The Geology of Erie County.

BY FREDERICK HOUGHTON, M. S.

The Geology of Erie County.

The geology of Erie county has to do with the consolidated rock formations which are exposed in the county and with their overburden of unconsolidated detritus, the result of erosion.

The Consolidated Rock Formations.

The consolidated rock formations belong to the Siluric and Devonic systems. The edges of the formations extend approximately northeast and southwest, and the county stretches north and south athwart these. Consequently in it are shown a large number of formations which rise like steps to the southward.

List of Formations Exposed in Erie County.

These are arranged from upper to lower, as they would appear in crossing the county from south to north.

Carbonic System		
Devonic System	Chemung	
	Portage	Wicoy shale
		Laona sandstone
		Gardeau shale
		Dunkirk shale
		Hanover shale
		Angola shale
		Rhinestreet shale
		Cashaqua shale
		Middlesex shale
	Genesee Beds	West River shale
		Genundewa limestone
		Genesee shale
	Tully Horizon	Pyrite layer
	Hamilton Beds	Moscow shale
		Tichenor limestone
		Ludlowville shale
		Skaneateles shale
	Marcellus Beds	Cardiff shale
		Stafford limestone
		Marcellus shale
	Onondaga Beds	Onondaga limestone
Siluric System	Salina Beds	Cobleskill limestone
		Bertie limestone
		Camillus shale

The Unconsolidated Deposits.

Owing to the long period of time during which erosive agencies were at work upon the rocks of Erie county and to the effects of the great glacier which overrode this area, planing the surface, transporting, depositing and mingling the detritus, the rock formations of the county have been in most places buried from view by their overburden of earth. The problems presented by the unconsolidated detritus are extremely complex.

Topography of Erie County.

Topographically the county is divided into three rather distinct areas, the lines dividing which are more or less well marked. Its topography depends primarily upon the underlying rock formations, partly upon the erosion which these have undergone, partly also upon the modifying action of the great glacier which at one time covered them.

The first area comprises the northern part of the county. It is limited at its southern edge by the "Ledge," an escarpment marking the outcrop of the Onondaga limestone. This "Ledge" extends from the Niagara river at Buffalo to Akron, and beyond into Genesee county. Northward from the "Ledge" to Tonawanda creek, the boundary of the county, the land is low and flat and is a portion of the southern part of the valley of Tonawanda creek.

The second area lies south of the "Ledge" and is bounded on the south and east by the ranges of hills which constitute the southeastern corner of the county. It slopes gently upward towards the south. Along the eastern border of the county it extends approximately from Akron to Wales. On the western edge it contracts to a narrow plain lying between the hills and Lake Erie.

The third area comprises the hills of southeastern Erie county. These rise slowly from the low-lying plain and reach at Concord the altitude of 1500 feet. Through these high lands numerous streams have cut deep valleys.

The Rock Formations.

All the rocks of Erie county are sedimentary, that is, they were laid down in water, either as detritus derived from the erosion of some land, or the minerals abstracted by living organisms from sea water and built up into their skeletons, or the minerals originally dissolved in sea water but deposited because of the drying up of the water containing them. The detrital rocks in Erie county are shales and sandstones. These shales represent both deep-sea and off-shore deposits of mud and fine silt, and perhaps, also, marsh deposits at sea-level. The sandstones are nowhere (extensive enough in Erie county) to warrant the belief that they were beach deposits. They are, like the shales, off-shore sea-bottom deposits of fine detritus and sand. The great limestone formations of northern Erie county represent two methods of deposition. First, the Bertie limestone with the underlying shale seems to have been laid down, partly at least, by the precipitation of the minerals in sea water consequent upon the drying up of the water containing them. The great deposit of Onondaga limestone in the northern part of the county is the accumulation of carbonate of lime abstracted from sea water by corals, crinoids and molluscs, and of silica by sponges, diatoms and other organisms.

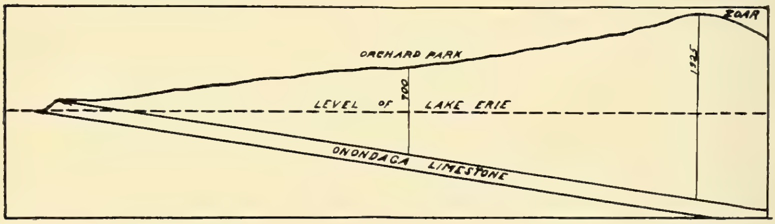


FIG. 1. Diagram to show how the southerly dip of the rocks of Erie county bring those exposed at the surface in the northern part far below the surface in the southern part.

All the rocks of Erie county dip to the southward, those in the northern part at the rate of about twenty five feet in a mile, those in the southern part probably at a greater inclination. As a consequence of this southward dipping, rocks which crop out at the surface at the northern edge of the county are brought by this inclination deep below the surface in the southern part. Thus the Onondaga limestone, which is encountered in northern Buffalo when cellars are being dug, is reached in drilling for gas at Orchard Park at from 600 to 700 feet below the surface, and at the northern bank of Cattaraugus creek at 1925 feet. Only part of this depth is due, however, to the inclination of the strata. Part is due to the difference in altitude between Buffalo and the other two places.

All the formations lie bedded as they were originally laid down, being neither folded nor, excepting in some few instances, faulted. With one exception all the beds meet conformably, the one inconformity being at the junction of the Onondaga and the Cobleskill, and representing the division between the Devonic and Siluric systems.

The rock formations of Erie county can be traced far to the eastward through the state. Some disappear west of Seneca lake. Others persist as far as the Hudson river. Nearly all are thicker at their eastward extension than in their Erie county exposures. Westward the formations in the middle of the section are terminated by Lake Erie under whose waters they disappear. The most northern formations cross Niagara river and enter Ontario then bend southward under the lake and reappear in northern Ohio. The most southern formations in the county, the strike of which is parallel to the south shore of Lake Erie, extend across northwestern Pennsylvania and northern Ohio.

Camillus Shale.

This thick formation of the upper Salina beds, named from Camillus, in Onondaga county, should be the surface rock of all that portion of Erie county north of a line connecting Buffalo and Akron. It is, however, almost entirely covered with drift and is occupied in this county by the southern side of the wide valley of Tonawanda creek. Few outcrops are visible and these are insignificant representatives of the great formation which is concealed from view. Eastward it extends as far as Albany county.

The Camillus shale is limited below by the Guelph dolomite of the Niagaran group. Above, it merges into the more calcareous and magnesian layers of the Bertie limestone which it joins without any definite line of demarcation.

In its eastward extension it is characteristically a grayish-green shale, weathering to a light pink. It contains gypsum in nodules and in thick beds.

A few of its upper layers may be seen on the Canadian side of the Niagara river below the International bridge and at the southern end of Grand Island. Lower beds are exposed at Edgewater on the eastern side of Grand Island. Irving Bishop has described these exposures as follows:

(1) Black shale in the river bed.

(2) Greenish shales containing nodules of gypsum, one and one-half feet.

(3) Light colored, soft, friable, gypseous shales, five feet.

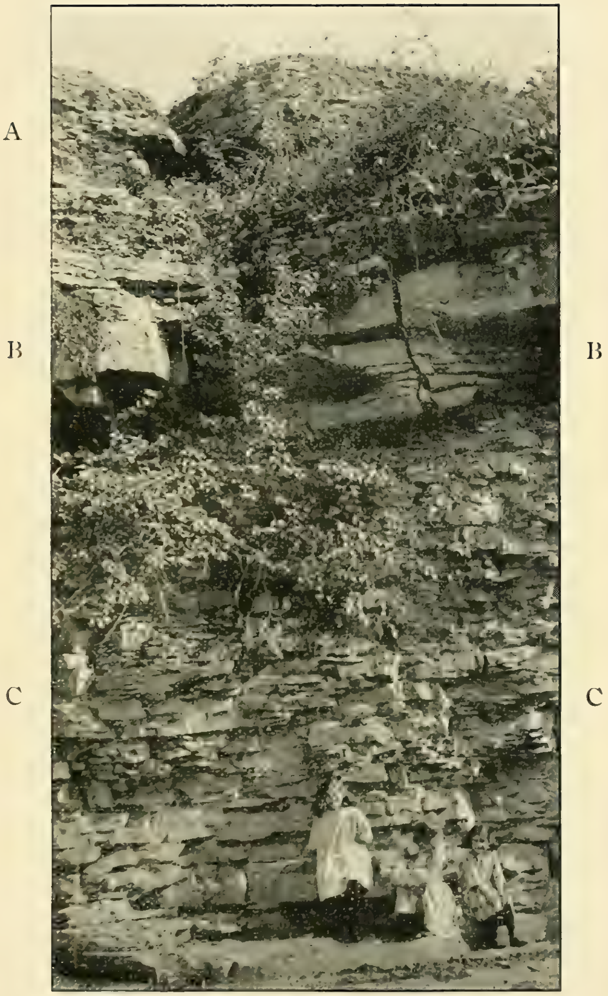
The Camillus shale is of great economic importance owing to its included deposits of gypsum. This is mined and calcined, and marketed under the name of plaster or plaster of Paris. It is the basis of the "hard wall plaster" in common use in the building trades, and combined with wood fibre it forms "wall boards" which have nearly supplanted lath and plaster in the construction of wooden houses. It is essential in mold making in potteries and in the manufacture of casts. It enters into the manufacture of cement.

In Erie county the mining of gypsum has been carried on extensively in the vicinity of Akron. In 1913, however, only one plant was at work and this was shipping the crude mineral to other places to be calcined.

Bertie Limestone.

The upper Camillus shales become more and more calcareous and magnesian in content toward the top and finally by gradual stages take on the nature of dolomitic limestone. This has received the name of Bertie limestone from the outcrops at Bertie, in Ontario. It extends eastward to Otsego county. A well core in the Museum of the Buffalo Society of Natural Sciences shows this limestone to be 55 feet thick where the formation crosses Main Street, Buffalo. The upper layers constitute a natural cement rock which has been burned for hydraulic cement. This cement rock lies in beds a foot thick or less, separated by thin, dark layers. The limestone is dark gray when first exposed but becomes lighter when exposed to the weather. Freshly exposed blocks tend to break with a decided conchoidal fracture when struck with a hammer.

The upper beds of this rock are exposed in the Barber Asphalt Company's quarry on Fillmore Avenue, Buffalo, where they may be seen to advantage. They are exposed in nearly all the deeper quarries along the "Ledge" from Buffalo to Akron. At Falkirk, 16 feet of the upper beds are exposed to advantage in the falls of Murder creek, and lower beds are to be seen in the creek bed between the falls and the railway bridge.



F. Houghton, Photo.

FIG. 2. Cliff at Murder Creek, Falkirk, showing A. Onondaga limestone, B. Cobleskill limestone, C. Bertie limestone.

The Bertie limestone beds in the quarries of the Buffalo Cement Works are characterized by the occurrence in them of an abundant and peculiar Eurypterid fauna. These eurypterids were crustaceans of the type of which the horse-shoe crab is a modern representative. Their fossil remains have been found in five colonies in New York, all in Siluric rocks. Of these five, the colony at the Buffalo Cement quarry has produced the finest and most numerous remains, and through the kindness of Mr. Lewis J. Bennett the Buffalo Society of Natural Sciences has acquired a large and exceptionally fine collection of these.

Besides the eurypterids a few other fossils have been described from the Bertie limestone. A list follows:

Eurypterida
    E. remipes Dekay.
    E. lacustris Hall.
    E. lacustris var. pachychirus Hall.
    E. dekayi Hall.
    E. pustulosus Hall.
    Eusarcus scorpionis Grote and Pitt.
    Dolichopterus macrochirus Hall.
    D. siluriceps nov.
    Pterygotus buffaloensis Pohlman.
    P. cobbi Hall.
    P. grandis Pohlman.
Ostracod
    Leperditia scalaris Jones.
Brachiopoda
    Orbiculoidea.
    Lingula.
Plants
    (Sea weed) Bythotrephis lesquereuxi. Grote and Pitt.

Analysis of cement beds, Bertie limestone, furnished to the State Education Department by Mr. Lewis J. Bennet.

Silica	11.48
Iron	.90
Alumina	17.50
Carbonate of lime	42.75
Magnesia (carbonate)	20.35
Potassium	1.00
Sodium	.80
Combined water and loss	5.22

Cobleskill Limestone.

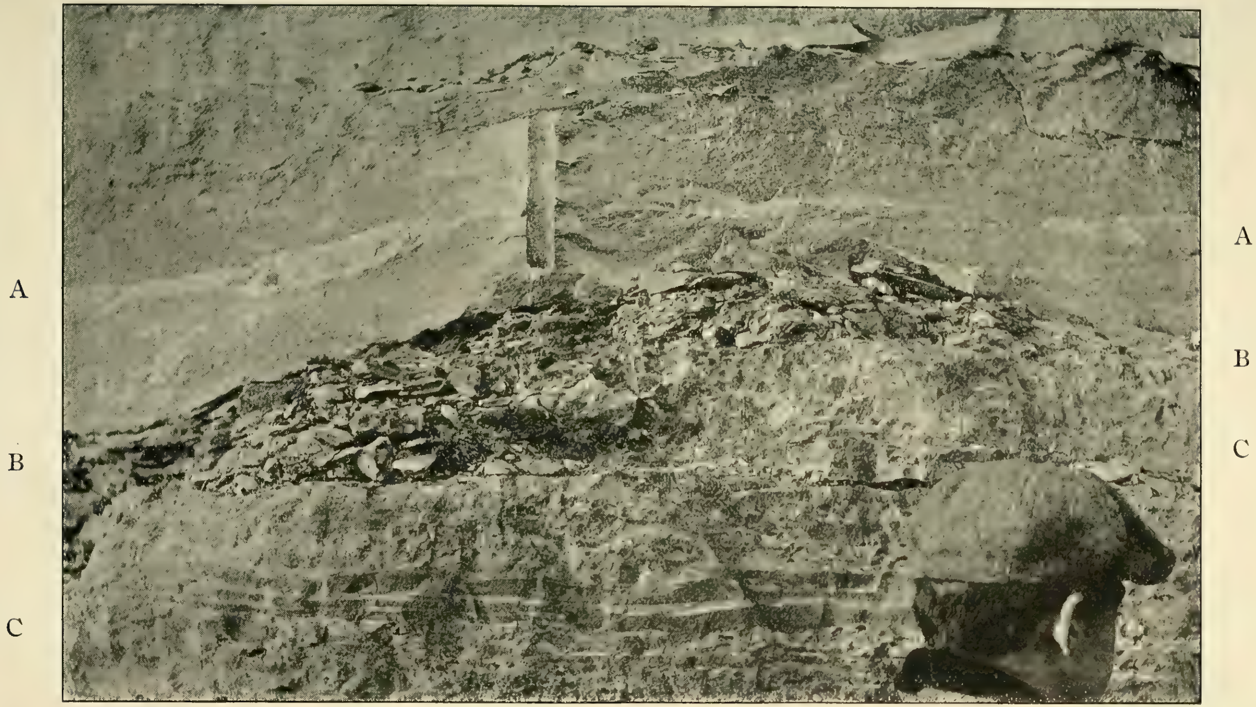
The Cobleskill limestone is a layer of limestone lying beneath the thin, shaly stratum representing the Oriskany horizon and separated by this shale from the overlying lower layers of the Onondaga limestone. It is the uppermost member of the Siluric system. Its contact with the overlying beds of the Devonic system is unconformable.

This limestone is the upper portion of the Waterlime group of Vanuxem and Hall. It was called the Coralline limestone by Gebhard and Hall. It was referred by Clarke and Grabau to the Manlius limestone. In 1902 Hartnagel considered it a western extension of the Cobleskill limestone, named from Cobleskill creek, Schoharie county. Amongst quarry owners and workers it is known as "bull-head rock."

In Ohio this formation is included in the Columbus (Onondaga) limestone (Stauffer, Geol. Sur. Ohio, 4th series, Bulletin 10). The eroded surface that marks the junction of the Cobleskill and the overlying Onondaga in Erie county does not exist in Ohio. Instead there is an eroded surface in all ways similar at the base of the Columbus limestone. This disconformity is regarded as marking the junction of the Siluric and Devonic systems. Therefore the Cobleskill of Erie county which is below this inconformity has been placed in the Siluric, although the similar beds in Ohio are placed in the Devonic. This inconsistency makes our present classification of these beds unsatisfactory.

The Cobleskill limestone in the exposures in Erie county is dark when freshly exposed and presents in a cross section a distinctly banded effect, its light surface being crossed by darker bands. It becomes lighter under the weather and after long exposure turns to a buff or even light yellow. It is saccharoidal and porous, and contains numerous, small, irregular cavities lined or partly filled with calcite crystals. These cavities seem to be in most cases molds of small corals, Cyathophyllum, hydraulicum, which have been dissolved out. The rock burns to a natural cement and has been quarried and burned in Buffalo for this purpose since 1850 and in Erie county at Williamsville since 1825.

The Cobleskill limestone may be seen to advantage in quarries at many points along the "Ledge." Its best exposures (1913) are in the Barber Asphalt Company's quarry on Fillmore Avenue, Buffalo, and at the Lockwood quarries east of Akron.



F. Houghton, Photo.

FIG. 3. Contact of Onondaga and Cobleskill limestones.
A. Onondaga limestone with included chert concretions.
B. Contact of Onondaga with eroded surface of Cobleskill, marking junction of the Devonic and Siluric systems.
C. Cobleskill limestone, showing characteristic banded effect and small cavities.

The contact of the Cobleskill limestone with the underlying Bertie limestone is not well marked. Between the two there is a gradual transition through two feet or more.

The contact of the Cobleskill with the overlying Onondaga limestone is very definite and well marked. Wherever the upper layers of the Cobleskill are exposed, as in quarries, the upper surface is found to be wavy or hummocky, an effect caused by irregular depressions of a depth of a foot or more. These depressions, and some channels observed in the Bennett quarry, seem to mark a period of erosion. The depressions are coated with a thin deposit of green shale, which follows the contours of the hollows and ridges to the depth of an inch or less. Above this shale the lowest layers of the Onondaga limestone follow the contours of the depressions in the Cobleskill, being separated from it by the thin shale.

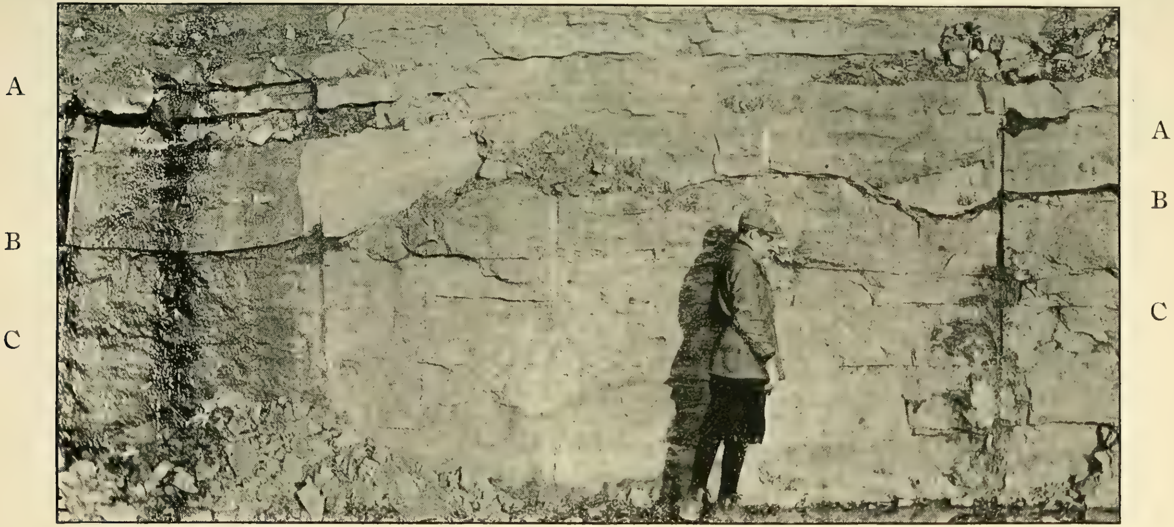
The Cobleskill was formerly of much economic importance owing to its burning to a cement. Portland cement has now supplanted it. It is also used in a limited way as a building stone.

This formation attains a thickness of 9 feet at Falkirk and 14 feet at Akron which is the greatest thickness in Erie county. In the Buffalo quarries it ranges from 2 to 5 feet.

Oriskany Horizon.

In southeastern and eastern New York are heavy deposits of sandstones, conglomerates and limestones which have received the name of Oriskany sandstone from their exposure at Oriskany, Oneida county. These arenaceous deposits are underlain in eastern New York by the heavy beds of the Helderbergian group which constitute the lowest members of the Devonic system.

In Erie county the Oriskany sandstone is absent. The upper surface of the Cobleskill presents an eroded appearance. Its regular horizontal bedding is broken by irregular hollows and depressions similar in all features to the erosion features of a limestone surface exposed to the action of streams or waves. In the bottoms of the depressions are thin layers of green shale and a conglomerate of water-worn fragments of limestone cemented together with quartz. This green shale and the accompanying breccia seem to represent the detritus of a somewhat prolonged erosion of a large superficial area of the Cobleskill limestone and this erosion is supposed to correlate with the beach deposits of Oriskany time.



F. Houghton, Photo.

FIG. 4. Eroded surface of Cobleskill limestone, considered to represent the Oriskany horizon and to form the contact between the Devonic and Siluric systems.

A. Lowest beds of Onondaga.
B. Eroded surface of Cobleskill.
C. The Cobleskill limestone.

In Ohio this breccia is represented by a conglomerate of "large and small water-worn pebbles of the underlying formation embedded in a matrix of Columbus limestone." This has been included in the Columbus (Onondaga) limestone.

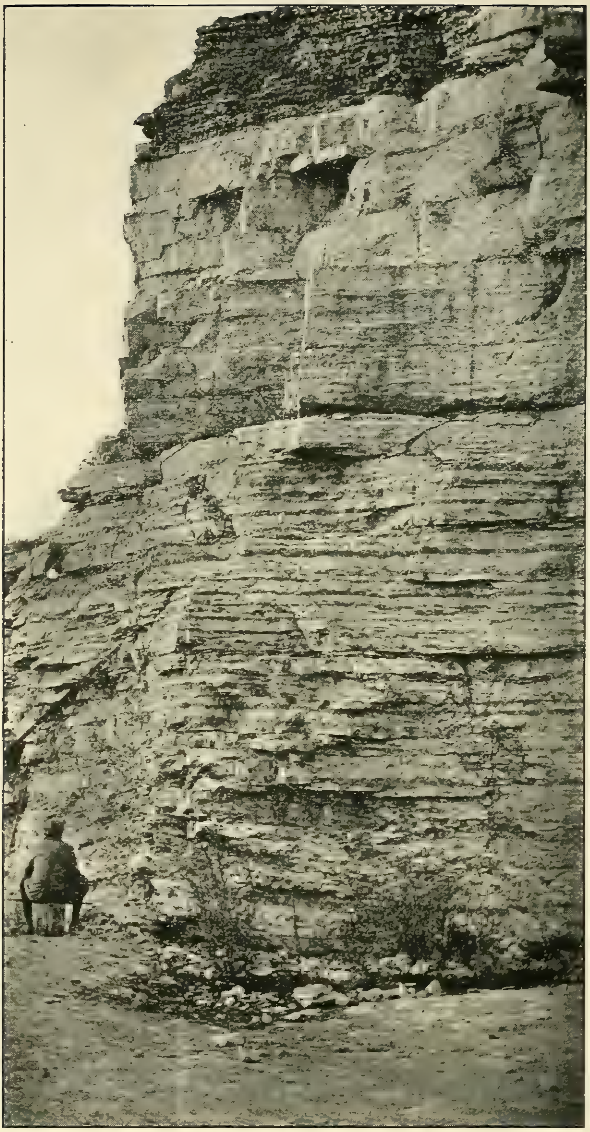
Onondaga Limestone.

Lying above the Cobleskill limestone and forming the cap of the escarpment which extends from the Niagara river to Akron is a heavy formation of limestone to which has been given the name of Onondaga limestone.

The name Onondaga limestone was used by Professor Hall to designate a layer of limestone lying between the Oriskany sandstone and a great mass of flinty limestone which lay in contact with the Marcellus shale above it. The flinty mass he named the Corniferous limestone. At the same time he expressed his opinion that the two limestone masses, the Onondaga and Corniferous, "for all practical purposes, may be regarded as one formation." Professor Eaton described them together as the Corniferous limerock. Dr. Clarke has abandoned the use of the name Corniferous and has applied the name Onondaga to all the deposits between the Marcellus shale and the Oriskany sandstone or its horizon, embracing the former Onondaga, Corniferous and Seneca. In Ohio this is called Columbus limestone.

The Onondaga limestone is the last great deposit of limestone in New York. It was preceded by the great deposits of Trenton, Clinton, Niagara and Salina times but was followed by minor beds only, intercalated between the tremendous deposits of shale of later Devonic time. It attains a thickness of 162 feet measured in a well of the Lackawanna Steel Company, but it thins eastward and in Onondaga county it is but 65 feet thick. It extends westward into Ontario. At all points it is constant in its lithological structure and its fossil content.

The Onondaga limestone is a mass of hard, compact bluish-gray limestone bedded in layers from a foot to two feet in thickness, usually separated by thin seams of carbonaceous material. Incorporated in the limestone are irregular nodules and layers of chert which in some of the layers make up a large proportion of the rock mass. The chert is black to bluish-gray in color, sometimes translucent in thin sections. It is extremely resistant to erosive agencies. In weathering, the lime in the



F. Houghton, Photo.

FIG. 5. Onondaga limestone, in Barber Ashphalt Company's quarry, Buffalo. Note weathered surface at the top.

rock dissolves away and leaves the cherty constituents behind on the eroded surface as a jagged, rough, sharp-edged coating. This jagged appearance of weathered Onondaga limestone is characteristic and not easily to be mistaken. The upper beds are of purer calcareous content and freer from chert.

The lowest layer of Onondaga limestone is a stratum of limestone entirely distinct lithologically and in fossil content from the beds above it. This is the layer originally called the Onondaga as differentiated from the upper flinty layers which had received the name of Corniferous. The lower bed differs in thickness at different points in the county. A good section in the Barber Asphalt Company's quarry shows it to be two feet thick there. At the Carroll Bros.' quarry at the spur of the West Shore Railway, near Clarence, the whole face of the quarry seems to be of this bed, which must have an approximate thickness of 30 feet. At the Fogelsonger quarry in Williamsville it is 35 feet thick. At Akron this bed thins again to 4 feet. It appears to be a great lentil, thickest at Williamsville and thinning rapidly toward the east and west.

The characteristics of this lentil are steadfast. Everywhere it is a hard, gray limestone containing chert, but unlike the overlying beds this chert is not disseminated throughout the mass but is in concretions. The rock is a coral reef rock and is one great mass of corals and crinoidal stems. The corals are Cyathophylloids and Favositids. Where the surface of the bed is laid bare in quarrying operations it is found to undulate and on it are to be seen corals in the position in which they stood when living.

The rocks of the Onondaga formation, taken together with the underlying beds of the Cobleskill and Bertie, constitute the most valuable mineral asset of Erie county. They furnish excellent stone for buildings, and for heavy abutments and riprap work, or wherever a rough but obdurate stone can be used. They are unfitted for finer work as their flinty constituents make them extremely hard to dress. The layers most free from chert have been burned for lime for nearly a century. For ballast and road metal they can hardly be surpassed. Crushed stone for these purposes is an important product of the quarries in the formation. The lowest bed is quarried for furnace flux.

The Onondaga limestone can be observed at nearly any point on the "Ledge" where it is broken by streams or where quarrying has been conducted. It crops out at Fort Erie and Erie Beach where its beds are at water level. It obstructs Niagara River forming rapids and maintaining the base level for Lake Erie. Black Rock derived its name from a ledge of Onondaga rock which jutted into the river there. An excellent section of fifty feet of its lowest layers is exposed in the Barber Asphalt Company's quarry, and smaller sections are exposed in various other quarries nearby. The lowest, or coral, layer can be seen to good advantage in the quarries at Williamsville, and better still at the Carroll quarry at Clarence. This lowest layer and about twenty feet of the upper layers are exposed in the Kelly Island quarry at the bend of the brick road just west of Akron and good exposures occur in all the quarries at Akron. Murder creek flows over the Ledge at Falkirk and exposes 15 feet of the lowest beds in an excellent section. Smaller sections of higher beds may be seen in Cayuga creek at Depew and in Buffalo creek at Winchester. Cellars excavated in the northern part of Buffalo reach to the lower beds of the rock and cellars in South Buffalo occasionally find the upper beds.

The formation is highly fossiliferous, but owing to the obdurate character of the rock it is very difficult to separate its fossils from their matrix. As a consequence the palaentology of this formation has been studied less than any other of the county. For the formation in the Canandaigua quadrangle Dr. Clarke lists the following:

Fishes, 3 species.

Crustaceans, 39 species.

Cephalopods, 13 species.

Pteropods, 3 species.

Gastropods, 38 species.

Lamellibranchs, 15 species.

Brachiopods, 48 species.

Crinoids, 4 species.

Corals, 30 species.

Marcellus Shale.

Lying above the Onondaga limestone is a mass of black shale which has been given the name of Marcellus shale, from Marcellus, Onondaga county. This name was originally given by Vanuxem to the black shales, now known as the Marcellus and Cardiff and the intercalated limestone bed, now known as the Stafford. The name Marcellus is now applied only to the lowest member of the old Marcellus. It extends eastward to Schoharie county and westward it probably correlates with the Olentangy shale of Ohio.

The Marcellus shale thus limited is a dense, black, slaty shale, highly bituminous and pyritiferous. It contains numerous concretions, often of large size, and occasional thin limestone layers. Lithologically it resembles the later Middlesex and Rhinestreet shales but it differs radically from them in fossil content. Its thickness is given as 49.6 feet in the well of the Lackawanna Steel Company.

Few outcrops of the Marcellus shale occur in Erie county. Exposures in Cayuga creek show only a few feet in two layers and these layers are separated by 15 feet vertical distance in which the shale is not exposed.

The following description of the beds immediately underlying the Stafford limestone is given by Miss Wood:

Stafford limestone

E. 12 inches gray calcareous shale with Orthis subulatum, Chonetes scitulus.

D. 12 inches gray, fissile shale with Liorhynchus limitare, Strophomena truncata.

C. 6 inches calcareous, dark gray shale with nuculites.

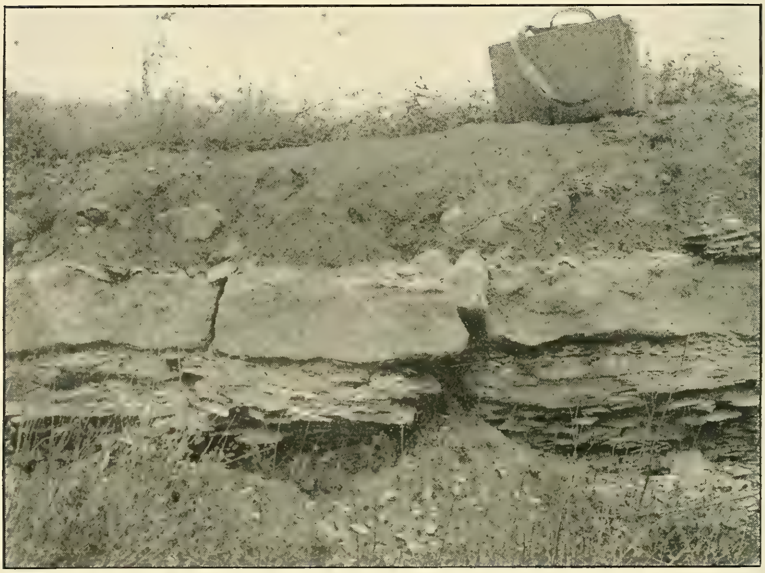
B. 4 inches extremely fissile gray shale, with Lunulicardium fragile, Chonetes mucronatus, Strophalosia truncata.

A. 4 inches gray calcareous shale breaking irregularly, with Styliolina fissurella.

Fifteen feet lower in the section there is a bed of dense black shale with iron pyrites and concretions. This is overlain by a bed of limestone a foot thick.

Stafford Limestone.

Bedded between the two black shales of the Marcellus beds is the Stafford limestone which, though present in Erie county, is a meager representative of its eastward extension. Hall described this thin limestone layer with which he limited upward the lower black (Marcellus) shale. He traced it from Flint creek, Ontario county to Le Roy, but seemingly he missed the exposure at Lancaster. He included it in the Marcellus. In 1888 Dr. Clarke designated this the Stafford limestone from its excellent exposure at Stafford, Genesee county.



F. Houghton, Phot o.

FIG. 6. Contact of Stafford limestone and Marcellus shale. New York Central Railway cut, north of Gardenville.

The Stafford limestone in its Erie county exposures is but eight feet thick. It lies between the black Marcellus shale below and the dark Cardiff shale above. When fresh it is of a dark chocolate color but becomes light gray after exposure. It splinters under the hammer, yet is substantial enough for building stone for which it has a limited use. Much of it is concretionary and at least one layer contains pyrite and chert.

Any outcrop of the Stafford along Lake Erie is deeply buried under drift. Stony Point probably marks its location there. It crosses Cazenovia creek an eighth of a mile below the Cazenovia street bridge and has been exposed there by sewer excavations. It forms a ledge across Buffum street at Seneca Indian Park where it is concealed by only two feet of soil. It crops out in Buffalo creek near the junction of Indian Church Road and Mineral Spring Road. Its lowest beds and its contact with the underlying Marcellus shale are shown in a cut made by the New York Central Railway a mile north of Gardenville. At Lancaster it is exposed in Cayuga and Plumbottom creeks.

At Lancaster it comprises eight beds as follows: (Woods.)

H.	12	inches.
G.	14	"
F.	14	"
E.	18	"
D.	10	"
C.	14	"
B.	6	"
A.	12	"

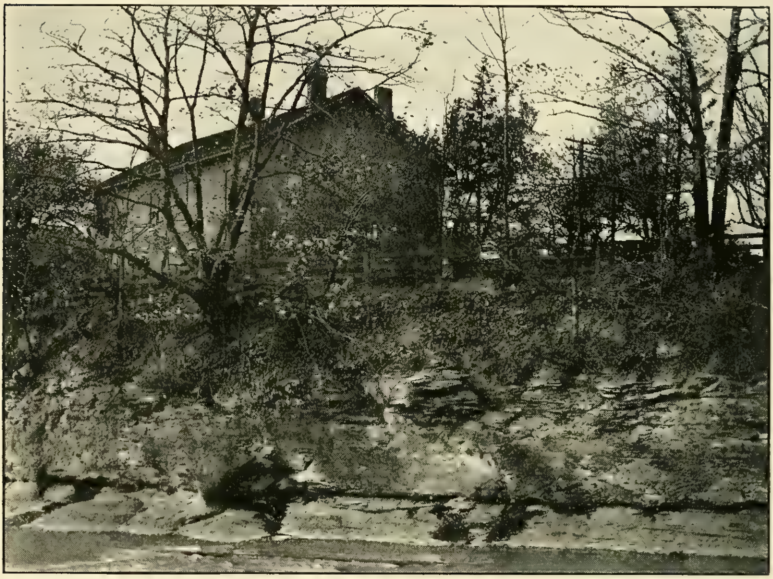
These beds have been the subject of a special study by Miss Elvira Woods who lists 72 species of fossils.

Cardiff Shale.

Following the Stafford limestone upward is a deposit of dark gray shale which forms the uppermost member of the Marcellus beds. This was called by Vanuxem "The Upper shales of the Marcellus." Because of its exposure in the village of Cardiff, Onondaga county it has been designated by Dr. Clarke the Cardiff shale. It extends eastward to Schoharie county.

The Cardiff shale comprises a series of dark gray, calcareous, or dense black shales including a few very thin limestone layers and spheroidal concretions in rows. In fresh exposures this shale is usually dense and black but it weathers after exposure to a dark, ashen gray. It is extremely fissile and breaks after exposure into thin, hard laminae with sharp edges. It weathers slowly in cliff sections and forms sheer ragged-edged cliffs. It is cut by cleavage planes at nearly right angles which cause its exposed surfaces to assume the appearance of lozenge shaped parallelograms.

At its base it rests directly upon the Stafford limestone. Its lowest beds contain limestone layers. Its uppermost layers merge insensibly into the Skaneateles shale, and no line of demarcation can be set down between them. Lithologically the two are identical. Dr. Grabau describes a hard layer containing Pteropods as the upper layer of the Cardiff. Regarding the division between the Cardiff and the Skaneateles, Hall says: (Geolog. 4th Dist. p. 177.)



F. Houghton, Photo.

FIG. 7. Cardiff shale, Cazenovia creek, Gardenville.

"For practical purposes there is little advantage in separating the upper division of this shale from the Hamilton group. The line of separation is nowhere well marked, the change in lithological character being gradual, while some of the fossils continue down from one to the other." The "upper division" spoken of is the Cardiff.

The Cardiff shale is exposed in the lake cliffs at Bay View. In the bed of Cazenovia creek below the bridge on Cazenovia Street its lower beds are to be seen, and at and above the bridge on the brick road in West Seneca its upper beds make a long rapid. Its upper beds, with the Pteropod layer which Grabau designates as its uppermost bed, crop out in Cazenovia creek a quarter of a mile below Lein's Park. A long exposure begins below Gardenville in Buffalo creek and extends up to the dam at Blossom.

Fossils are not abundant in the Cardiff shale. In the lower beds immediately above the Stafford Miss Wood has found the following:

Ceratopora Dichotoma Grabau.

Brachiopods :

Chonetes lepidus Hall.
Liorhynchus limitare Vanuxem.
Atrypa reticularis Linne.
Ambocoelia umbonata Conrad.
Meristella barrisi Hall.
Pterochaenia fragilis Hall.
Styliolina fissurella Hall.
Orthoceras aegea Hall.
Phacops rana Green.

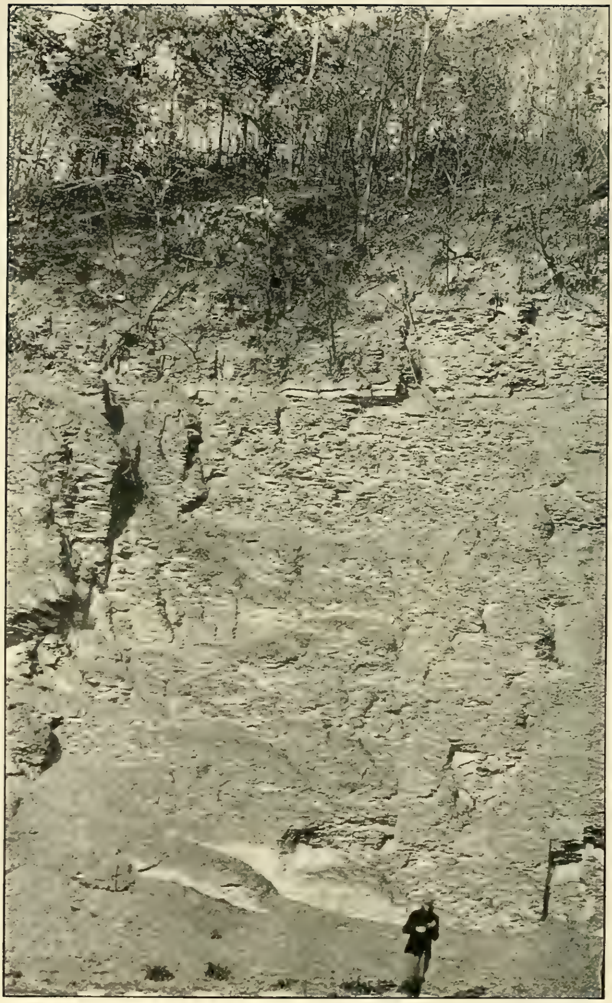
Dr. A. Grabau adds to this the following from the Bay View and Athol Springs cliffs:

Tentaculites gracilistriatus Hall.
Lunulicardium fragile Hall.
Nautilus marcellensis Vanuxem.
Chonetes mucronata Hall.
A few carbonized plant remains.

Skaneateles Shale.

This name was applied by Vanuxem to the shales exposed at the northern end of Skaneateles lake. Hall gave it no name, merely referring to it as "an olive often bluish fissile shale." Dr. Grabau calls it the "Transition shale."

The Skaneateles shale lies between the Cardiff shale below and the Ludlowville shale above. It is the lowest member of the Hamilton beds. In Erie county it is a mass of light gray shales from 30 to 60 feet thick. Its lowest beds are dark, almost black, but it becomes lighter upward and its uppermost beds are a light,



F. Houghton, Photo.

FIG. 8. Cliff of Skaneateles shale, Cazenovia creek above Ebenezer.

olive gray. It contains numerous small concretions from an inch to a foot in diameter, many of which are composed wholly or partly of iron pyrites. It is cut by two series of cleavage planes at an angle a little greater than 90 degrees. In cliffs, these cause a series of smooth faces and angles sometimes extending vertically for ten feet or more.

The Skaneateles shale merges into both the Cardiff below and the Ludlowville above. No definite line of contact can be distinguished. Dr. Grabau has designated a bed called the Pteropod bed as the bed limiting it below and a calcareous bed containing Strophalosia truncata as its uppermost bed.

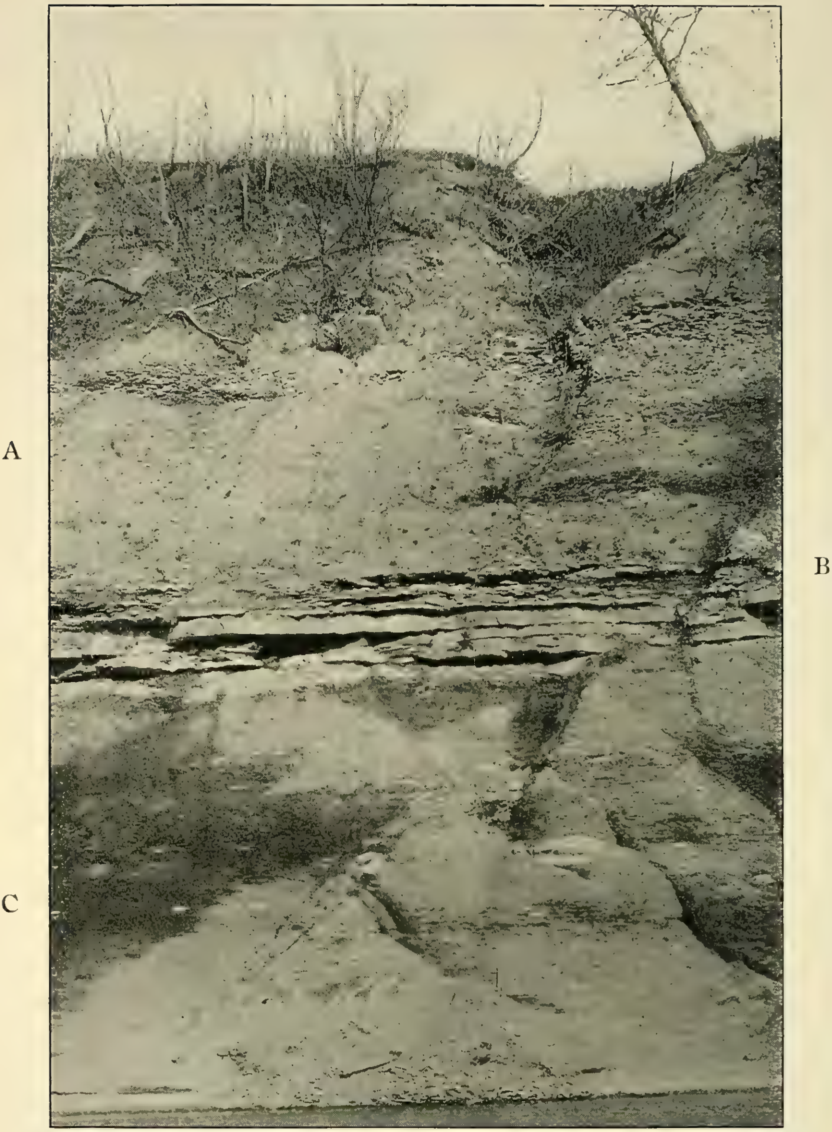
The Skaneateles is exposed in the Lake Erie cliffs at Athol Springs and in the lower part of Avery's creek. In Smoke's creek almost the entire formation is shown at the Town Line Road on the south branch. In Cazenovia creek it forms sheer cliffs almost continuously from below Lein's Park to the cliffs above the bridge at the terminus of the Buffalo Southern Railway.

At this latter point the cliff is 42 feet high. Six feet from the top of the rock section is a six inch layer of limestone which is probably the layer designated by Grabau as terminating the formation upward.

At Blossom on Buffalo creek is a four foot ledge of limestone which Bishop referred to the Skaneateles as a "basal layer." In many respects it is unique. It is made up of four layers, all concretionary. Below these are about four feet of gray shale. The shale layers immediately below the limestone are exceedingly rich in fossils, mainly cyathophylloids of large size with a few brachiopods and some trilobites. The fauna resembles in every respect that of the Moscow and Encrinal, yet the ledge is certainly near or at the junction of the Skaneateles and Cardiff.

Ludlowville Shale.

Superimposed upon the gray mass of Skaneateles shale and merging downward into it is a somewhat similar gray deposit of shale which of late years has regained the original name assigned it by Hall. He named it the Ludlowville shale, partly from its exposure at Ludlowville, Cayuga county, partly because he believed this shale was of the same age as that of Ludlow, England. This name later gave place to Vanuxem's designation, the Hamilton shale and has been so called until recently. It has now regained Hall's designation, the Ludlowville shale.



F. Houghton, Photo.

FIG. 9. Cliff at Bullis Road, Buffalo creek.

A. Moscow shale.
B. Tichenor limestone.
C. Ludlowville shale.

The Ludlowville shale is a heavy mass of bluish gray, calcareous shale extending from Lake Erie eastward to beyond Cayuga lake and at all points keeping the same characteristics of color, texture and content. It is often without strong cleavage planes but is somewhat fissile. It weathers into a sticky, gray clay. It includes several rather constant layers of limestone and abundant small concretions. Its upper beds lie in contact with the Tichenor limestone. Its lower beds merge into the Skaneateles below it. So gradual is its transition that no line of demarcation can be set. Grabau has considered the line of division to be immediately beneath a bed containing Strophalosia truncata, 50 feet below the Encrinal limestone.

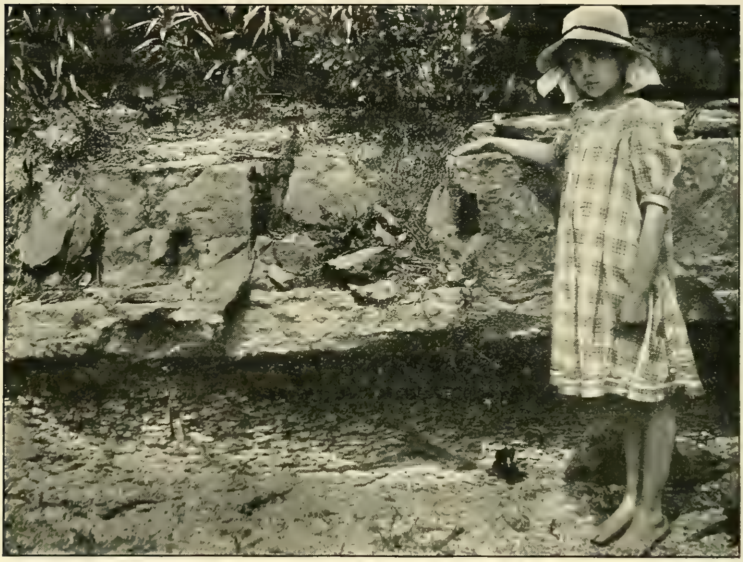
The Ludlowville is exposed in Eighteen Mile creek for the first mile of its course, in the lake cliffs at its mouth and as far north as Avery's creek. The whole formation is shown in the south branch of Smoke's creek at Windom and in the north branch at Town Line Road where it forms a cascade. In Cazenovia creek it appears in cliffs from the bottom of the dam at Springbrook to the Skaneateles cliff at the terminus of the Buffalo Southern Railway. In Buffalo creek its upper beds show at the bridge at the Bullis Road and the shales exposed in the cliffs north of Springbrook station are probably in the middle beds.

The whole formation is characterized by an abundance of fossils, and because of the softness of the matrix these may be removed with ease in perfect condition. A few thin beds are exceptionally rich. The lowest of these, the Nautilus bed, yields Nautilus magister of large size. Above this, within a vertical distance of eight feet, are the Pleurodictyum beds and the Trilobite beds, all exceedingly rich in fossils, many of which are rare in other formations. At the top of the formation and immediately below the Tichenor limestone are two beds, the Stictopora bed and the Demissa bed which yield an immense number of beautifully preserved fossils in great variety.

Tichenor Limestone.

Limiting the Ludlowville shale above is a thin but constant bed of limestone which was named by Hall the Encrinal limestone. This has been rechristened by Dr. Clarke the Tichenor limestone from its exposure at Tichenor Point on Canandaigua lake. It extends eastward to Cayuga county.

In Erie county the Tichenor limestone varies from a foot to four feet in thickness. It occurs in layers which vary in number at different outcrops. At Windom it consists of two layers, each a foot thick. At Springbrook it comprises six layers totaling three feet. At Bullis Road it is four feet thick and is made up of ten layers.



F. Houghton, Photo.

FIG. 10. Tichenor limestone at Town Line Road, north branch of Smoke's creek.

It is highly pyritiferous and in weathering shows iron stains. At Springbrook the bottom surface of its lowest layer is coated with a half inch of iron pyrite. It is impregnated with petroleum which fills all cavities and oozes out from its surfaces. It is semi-crystalline in structure and refractory under the hammer. It is durable as a building stone but unsightly because of its iron stain, but it is used in a small way locally for bridge abutments and cellar walls.

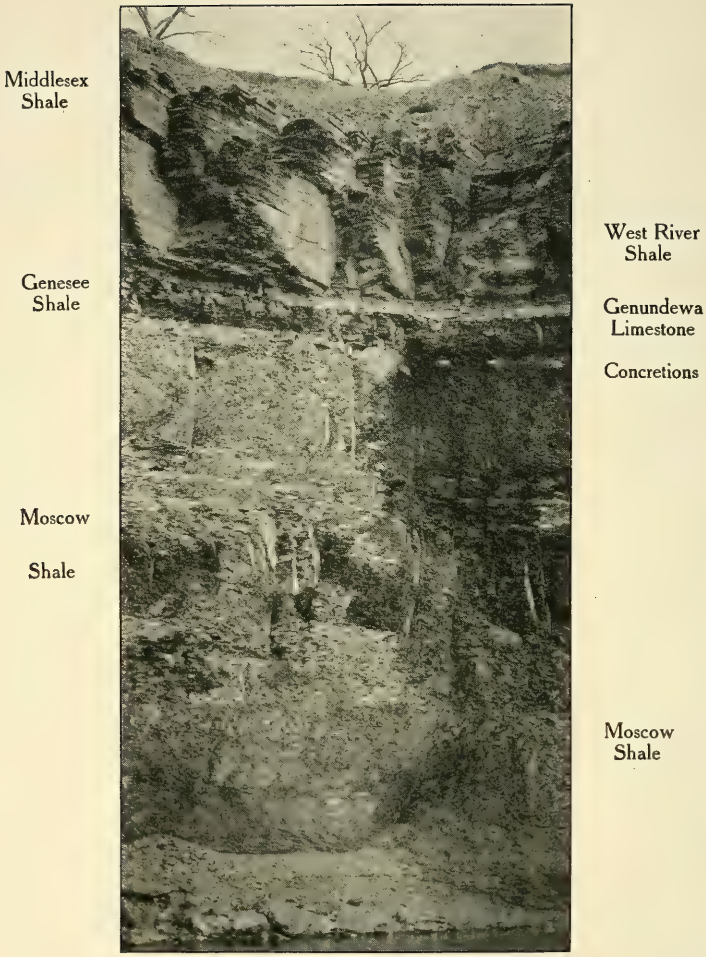
It is highly fossiliferous. Its bulk is mainly coarsely comminuted fragments of crinoids, corals and shells, and enclosed in this matrix are entire fossils of many species. Favosite corals abound, many being a foot or more in diameter. The rock is sufficiently obdurate to make it very difficult to separate the fossils from the matrix.

The Tichenor limestone is exposed at Eighteen Mile creek below the railway bridges and in the lake cliffs south of the mouth of the creek. It dips under the lake just north of the mouth of Pike creek. It forms cascades in the south branch of Smoke's creek at Windom and in the north branch at the Town Line Road. It is the base of the dam at Springbrook and forms a series of cascades in Buffalo creek at Bullis Road. The Bullis Road outcrop of this limestone is perhaps the best in Erie county. Here the layers are separated by thin, shaly layers and the upper layers are more nearly hard calcareous shale than limestone, yet the entire formation, including the shaly separations, is hard enough to have allowed a block nearly four feet thick to drop out of the cliff at one point. The middle layers are composed entirely of fossils mostly large cyathophylloids, favositids and crinoidal stems with an abundance of the characteristic lamellibranch Mytilis, the Spirifer granulosus, and bryozoa. The favositids form large heads often more than a foot in diameter and many of the crinoidal stems are a foot or more long and three-eighths of an inch thick.

Moscow Shale.

The uppermost member of the Hamilton beds is the gray shale which has taken its name from a fine exposure at the village of Moscow, in Livingston county. This shale lies immediately above the Tichenor limestone and is limited above in Erie county by a pyritiferous layer of shale. It includes in its upper layer a band of concretionary limestone two inches thick at Springbrook but varying with the locality. The shale is uniformly gray, rather free from cleavage planes and it weathers to a sticky, gray clay. The bottom layers, especially those immediately above the Tichenor limestone, are highly calcareous and firm enough to break out in rough blocks. It contains occasional thin layers of concretions or concretionary limestone. The lowest layers immediately above the Tichenor limestone are very fossiliferous.

Its contact with the underlying Tichenor limestone is well defined. Its upper limit is well marked by a pyritiferous band, which shows in a cliff face as a brown band.


Middlesex Shale
Genesee Shale
Moscow Shale
West River Shale
Genundewa Limestone
Concretions
Moscow Shale

F. Houghton, Photo.

FIG. 11. Succession of formations from Middlesex shale downward to the lowest layers of Moscow shale. Cazenovia creek, Springbrook.

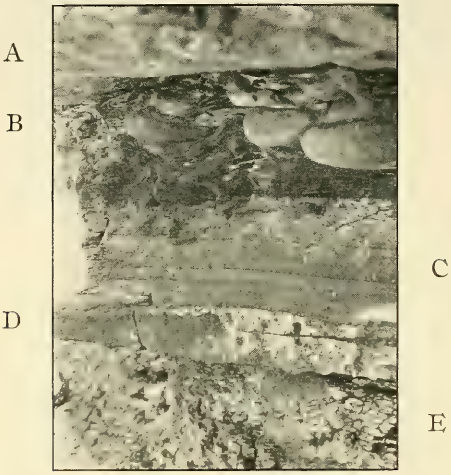
The Moscow shale is exposed in the Lake Erie cliff from Pike creek to Wanahkah and in Eighteen Mile creek between its mouth and the railway bridges. In the south branch of Smoke's creek it is well exposed in the stream bed and in cliffs from the small cascade formed by the Tichenor at Windom to the bridge over the Benzing Road. Its lowest beds, with an abundance of fossils, crop out in an obscure gully opening into Smoke's creek at Windom and also just above the cascade where the contact between them and the Encrinal is well shown. The upper beds and their contact with the pyritiferous layer are exposed in a small gully on the east bank, and also just below the bridge over the Benzing Road. The lower and middle beds are well exposed in the north branch of Smoke's creek for a half mile above the cascade at the Town Line road. The entire formation, excepting about three feet of the lower beds, is shown in one cliff section at Springbrook in Cazenovia creek, where the beds are limited above by a four inch bed of pyrite. In Buffalo creek a cliff section at the Bullis road bridge includes all the lower and middle beds.

The Moscow shale thickens rapidly eastward in the county. At Eighteen Mile creek it is seventeen feet thick, at Smoke's 52 feet, and at Springbrook nearly 50 feet are exposed above the lower beds.

Pyrite Layer, Tully Horizon.

In the central part of New York the Hamilton beds and the Genesee beds are separated by a stratum of limestone which from its exposure at Tully in Onondaga county has been designated the Tully limestone. This limestone is absent in Erie county but its horizon is marked by a layer of shale strongly impregnated with iron pyrites. At some exposures this layer becomes a solid layer of pyrite from an inch to four inches thick.

This pyrite layer is well shown in Cazenovia creek at Springbrook. The upper beds of the Moscow are well shown and capping these is a four inch layer filled with pyrite, above which are the black shales of the Genesee beds. At one point of this exposure the shale disappears and in its place is a four inch layer of solid pyrite. This is a lentil about 30 feet long in the cliff. This projects from the cliff as a ledge, and on the stream bed are large blocks broken off as the softer shale is undermined. The pyrite is extremely hard and is a mass of casts of fossils which have been replaced by the pyrite. Fossils from this layer at other points have been the subject of a monograph by Frederick B. Loomis.



F. Houghton, Photo.

FIG. 12. Section of cliff, Cazenovia creek, south of Springbrook.
A. Genundewa limestone, overhanging.
B. Concretions imbedded in black shale.
C. Genesee black shale.
D. Pyrite layer.
E. Moscow shale.

The pyritiferous shale, also, is filled with fossils all of which have been replaced by the pyrite.

Genesee Beds.

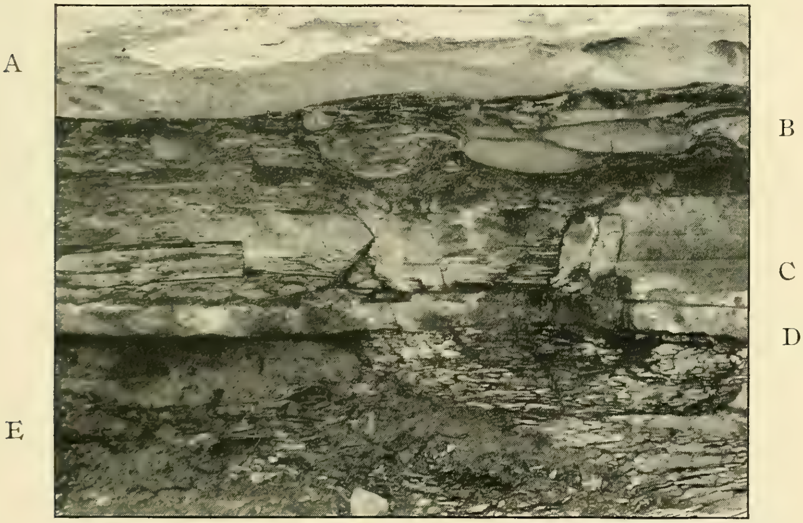
James Hall considered the Tully limestone a line of demarcation. The fauna of the beds above the Tully differs radically from that below it. Conditions favorable to the great profusion of marine life which characterized the seas of the period during which the Hamilton beds were laid down seem to have come to an end with the deposition of the Tully limestone. The difference is more marked in the western part of the state than in the eastern where there is more or less mingling of the faunas of the Hamilton and Genesee beds.

Lithologically the beds above the Tully differ radically from those below it. The deposits of lime in western New York which characterized the lower members of the Devonian come to an end with the Tully and thereafter the beds are characterized by an ever increasing sandiness which in Erie county culminates in the heavy bedded sandstones of the upper Portage.

The Genesee beds begin above the Tully limestone, or where, as in Erie county, this is absent, above the pyritiferous layer representing the Tully. The lowest beds are of dense black shale. These end abruptly with a thin bed of limestone which is followed by sandy dark gray shales. The beds attain in Erie county a thickness of not more than 20 feet. They thicken eastward until at Mt. Morris on the Genesee river they are 180 feet thick.

Genesee Shale.

At two localities in Erie county there appears above the pyrite layer a thin band of black shale. This is the dwindled representative of a mass of dense, black, slaty shale which in the



F. Houghton, Photo.

FIG. 13. The Genesee shale.

A. Genundewa limestone.
B. Concretionary layer.
C. Black shale, 19 inches.
D. Pyrite layer (Tully horizon).
E. Moscow shale.

Genesee valley lies between the Tully and the Genundewa limestone. At Naples this bed is 95 feet thick but it thins toward the west and eastward it merges with the West river shale in Chenango county. At Mount Morris it is 82 feet thick.

In Erie county this formation has practically disappeared. At Springbrook it shows in the cliff face as a dark band from 19 to 26 inches thick. At Smoke's creek it is absent but is represented by a row of concretions. At the mouth of Pike creek in the lake cliffs it is 12 inches thick.

At the Springbrook outcrop where it shows to the best advantage the shale is dense, black and slaty. It lies directly upon the layer of pyritiferous shale. Its upper layer is a layer of flat concretions a foot or less in diameter which lie in direct contact with the Genundewa limestone above.

The Genesee shale is nowhere abundantly fossiliferous. No fossils have been described as having been found in the formation in Erie county. Numerous land plant remains found by the writer at the mouth of Pike creek in loose, black shale were referred by him to the Genesee.

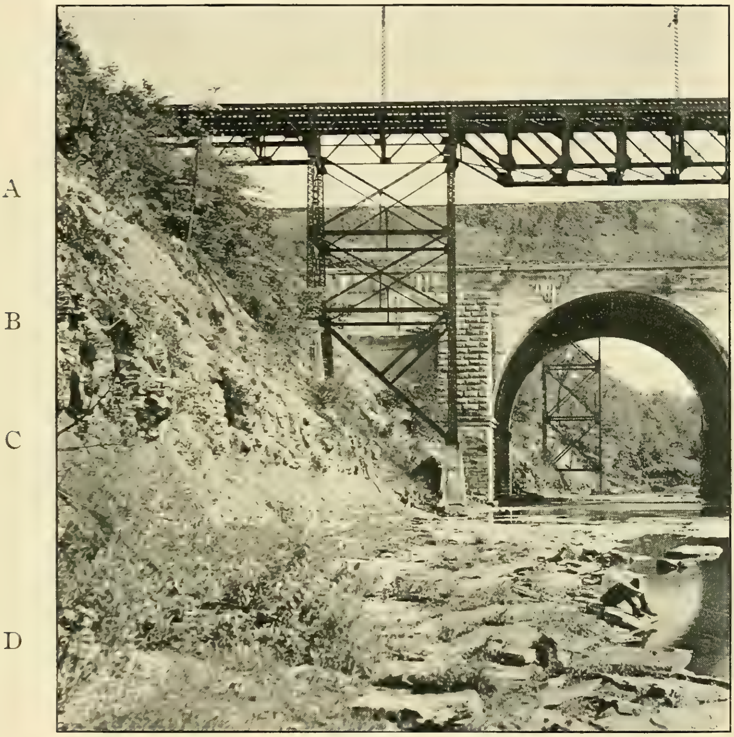
Genundewa Limestone.

Lying in the middle of the black and dark gray shales of the Genesee beds is a thin but persistent layer of limestone which, because of the presence in it of innumerable shells of Styliolina fissurella, came to be known as the Styliola band or the Styliolina limestone as named by Dana. This name has been changed to Genundewa limestone due to its exposure at Bare Hill, on the east side of Canandaigua lake, the alleged Genundewa of Seneca tradition.

The Genundewa limestone, where exposed in the gorge of Eighteen Mile creek, is from four to six inches thick and concretionary in character. It is made up of two layers, the Styliola and the Conodont.

The Conodont bed lies in immediate contact with the Styliola or it is separated by thin layers of dark shale. The Styliola is composed almost entirely of the microscopic shells of Styliolina fissurella. It is argillaceous and gives off the characteristic clayey odor when breathed upon.

The Conodont bed is concretionary and irregular in its bedding. At some exposures it is absent altogether. Its surface undulates and the resulting hollows are filled with thin laminae of shale. Newly fractured surfaces show a coarsely crystalline structure, and weathered surfaces are rough owing to the weathering out of the tiny fossils which make up the bulk of the mass.



F. Houghton, Photo.

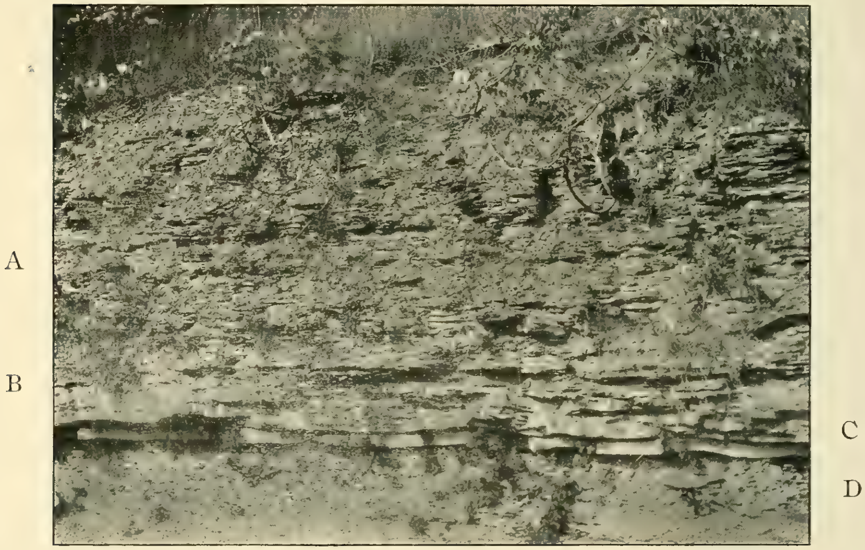
FIG. 14. Cliff at railway bridges, Eighteen Mile creek, Lake View, showing
A. Cashaqua shale.
B. Middlesex shale.
C. West river shale.
D. Genundewa limestone, which forms the bed of the creek at this point.

Included in the Genundewa limestone is a band of dark shale and thin limestone layers totalling in all twelve inches thick. This lies immediately above and in contact with the Styliola layer.

The Genundewa limestone is extremely fossiliferous. The Conodont layer, especially, is rich in fish remains and in the peculiar organisms which have given it its name. The limestone layers immediately above the Styliola layer and included in it show abundant remains of a peculiar crinoid.

West River Shale.

Lying above the Genundewa limestone is a mass of dark gray shale which is the uppermost member of the Genesee beds. To this has been given the name West river shale from its occurrence in the valley of West river at the head of Canandaigua lake. It was included by Hall in his Genesee slate and to distinguish it from the lower black Genesee shale it was later named the gray Genesee shale. It is recognized as far east as Cayuga lake.



F. Houghton, Photo.

FIG. 15. Cliff showing West river shale and Genundewa limestone, Smoke's creek, at Benzing road.

A. West river shale.
B. Thin limestone and shale layers.
C. Genundewa limestone.
D. Moscow shale.

The West river shale in Erie county is composed of dark gray or chocolate colored shales interbedded with thin layers of hard dark shale. It merges gradually downward into the Genundewa, the junction being a thin band of shale in thin laminae alternating with thin limestone layers. It is fissile, and splits readily into thin, sharp laminae with sharp edges. It weathers rather quickly in a cliff into a rough, ragged face with innumerable sharp edges projecting from it.

The West river thickens toward the east. Grabau gives its thickness at Eighteen Mile creek as eight and a half feet. At Smoke's creek it is fourteen feet, and at Cazenovia creek slightly more. At Mount Morris it is sixty-five feet and at Naples ninety feet thick.

The West river shale is exposed in the Lake Erie cliffs at the mouth of Pike creek. It appears in the bed of Eighteen Mile creek just above the railway bridges and rises in the cliffs until it disappears at their top just above the bridge over the Lake Road. A good section is exposed in the south branch of Smoke's creek at the Benzing road. Its best exposure in Erie county is in the cliffs of Cazenovia creek at Springbrook, where its contact with the Middlesex above it and the Genundewa below is well defined.

Fossils are rare in the shaly layers but less rare in the limestone layers at the bottom. Pterochaenia fragilis is the only fossil listed as being found in the West river of Erie county.

The Portage Beds.

The Portage beds comprise that portion of the rock formation ascribed by Hall to the Devonic system lying between the Genesee beds below and the Chemung beds above. They approximate twelve hundred feet in thickness and stretch completely across the state. They extend southwesterly across the northwest corner of Pennsylvania and correlate with the Ohio shales of Ohio.

In general they comprise alternating masses of black and gray shales which increase steadily upward in sand content. They begin with the Middlesex shale, a black shale without sand. In the Rhinestreet, also a black shale, are occasional sandstone layers. These increase in number in the Angola and Hanover shales and finally culminate in the heavy bedded sands of the Nunda sandstones.

The present subdivision of the Portage beds in Erie county is unsatisfactory. The Middlesex, Cashaqua and Rhinestreet are constant enough in their characteristics to permit identification at distant points. With the other subdivisions this is difficult. Each varies at different points and each blends with the one above and below it. For instance there is no line of demarcation between the so-called Angola and Hanover divisions of the Hatch shales. One merges into the other. Nor are they so different at their most different parts to admit of positive identification. Similarly the Hanover merges into the Gardeau for although they are separated in theory by the black band of the Dunkirk shale, this band is merely a thicker band than three others which are included in the Hanover. Similarly, no line of demarcation exists between the Gardeau and Laona sandstone, nor does the Wiscoy differ in character from the Gardeau.

All the beds except the Rhinestreet increase in thickness toward the east and at the same time increases in sandiness.

Middlesex Shale.

The Middlesex shale is a thin band of hard black shale lying between the gray Cashaqua shale above and the dark West river shale below. Originally this was included by Professor Hall in the Genesee slates in which he also placed all the black and dark gray shales lying between the Tully and the gray Cashaqua. This upper member of the original Genesee slate has been referred by Clarke to the Portage as its lowest member. It was named from its complete exposure in Middlesex valley near the head of Canandaigua lake. It disappears at Seneca lake. East of Seneca lake it seems to have merged with the West river shale.

In Erie county the Middlesex shale is a thin bed of hard, black, slaty shale with a chocolate streak and a strong bituminous odor. It is crossed by two series of cleavage planes along which it separates into parallelograms. It splits easily into thin laminae the surfaces of which after weathering are stained with iron.

It increases in thickness towards the east. Grabau gives its thickness at Eighteen Mile creek as nine and a half feet though Luther gives its thickness at Smoke's creek as six feet. In Ontario county it is thirty-five feet thick.

It is to be seen in the cliffs at the mouth of Pike creek. Its contact with the overlying Cashaqua and the underlying West river can be seen in the Eighteen Mile creek gorge just above the railway bridges. An excellent exposure of the upper surfaces of its layers with numerous large plant remains is found in the bed of the south branch of Smoke's creek just above the Benzing road. A fine exposure showing the contact with the underlying West river shale can be seen in Cazenovia creek cliffs south of Springbrook.

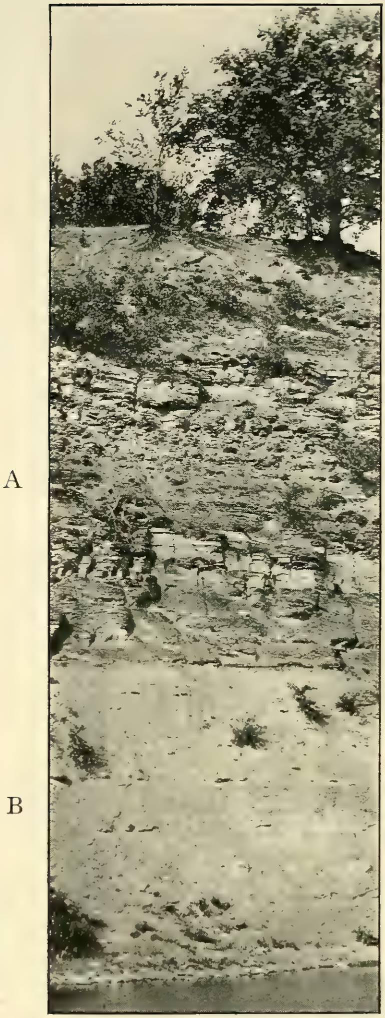
Fossils are rare. A few layers at some points show abundant plant remains. Lingula ligea is the only fossil listed from Erie county. A large fish plate was found by the writer in its lowest beds at Smoke's creek.

Cashaqua Shale.

Lying between the hard, black Middlesex shale and the equally hard, black Rhinestreet is a soft, gray shale, which from its excellent exposure on Cashaqua creek in the Genesee Valley, was designated by James Hall the Cashaqua shale.

It consists of an olive-gray shale which after exposure breaks down readily into a gray clay. Included in the mass are rows of flattened concretions which in some locations tend to coalesce into thin, irregular flags. Its thickness is given by Hall as thirty-three feet at Eighteen Mile creek and by Luther as averaging forty-five feet in the county. It extends eastward to Cayuga lake.

The contact of the Cashaqua with the shales above it and below it is fairly definite. Seen at a distance, the Cashaqua when exposed in a cliff, is a well defined gray band lying between two black bands, with sharply marked lines of demarcation. Seen more closely the gray is found to merge gradually into the black shales through a foot or more of brown or chocolate colored shale.



F. Houghton, Photo.

FIG. 16. Cliff at North Evans, Eighteen Mile creek, showing contact of Rhinestreet and Cashaqua.

A. Rhinestreet.

B. Cashaqua.

The Cashaqua shale is exposed in the lake cliffs at and above the mouth of Pike creek. It is well shown in the cliffs of Eighteen Mile gorge at and above the railway bridges where its contact with both Middlesex and Rhinestreet is visible. It forms a cliff and a long horizontal section in the south branch of Smoke's creek at the dynamite storehouses. It is exposed in Cazenovia creek about two miles above Springbrook and at East Elma on Buffalo creek. The characteristics exhibited in all these exposures are identical.

Fossils are fairly abundant. A list given by Luther of forms abundant in this vicinity follows:

Goniatites:
  Probeloceras lutheri Clarke.
  Gephyroceras holzapfeli Clarke.
  G. cf. domanicense Holzapfel.

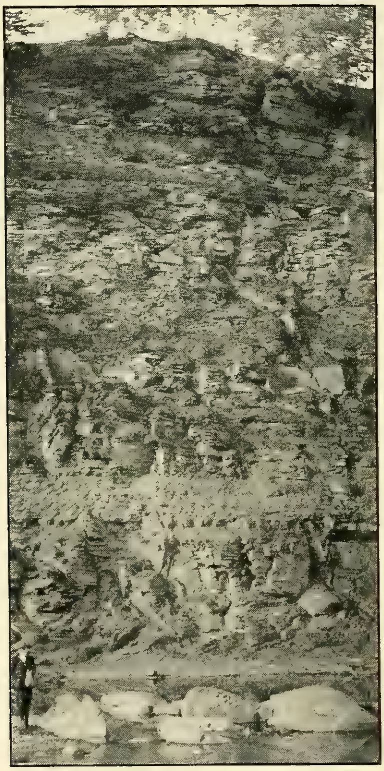
Lamellibranchs:
  Lunulicardium pilosum Clarke.
  Pterochaenia fragilis Hall.
  P. elmensis Clarke.
  Buchiola retrostriata v. Buch.
  B. lupina Clarke.

Gastropod:
  Loxonema noe Clarke.

Rhinestreet Shale.

The Rhinestreet shale comprises a thick mass of dark, bituminous shales lying between the gray Cashaqua below and the gray Angola shale above. Originally it was included in the Gardeau shales. Later these were separated and the name Black Naples shale was applied to this black band to distinquish it from the underlying Gray Naples shale, now called the Cashaqua. Its present name was given to it because of its exposure at Rhinestreet near Naples. At its most eastward exposure at Seneca lake it is but two feet thick.

In Erie county it is a succession of fissile black shales, 185 feet thick, in thick beds alternating with thickly bedded, dense, hard, black, slaty shale. The shale is highly bituminous and emits a strong odor of petroleum when newly fractured. All the more dense shales have strongly marked cleavage planes. At intervals, in the vertical succession, are layers of calcareous concretions. Many of these are septaria, and many are of huge size. Septaria six feet in diameter and four feet thick are numerous. The septaria seen in cross section are crossed by series of radiating and concentric veins filled with white, black and brown crystals of calcite.

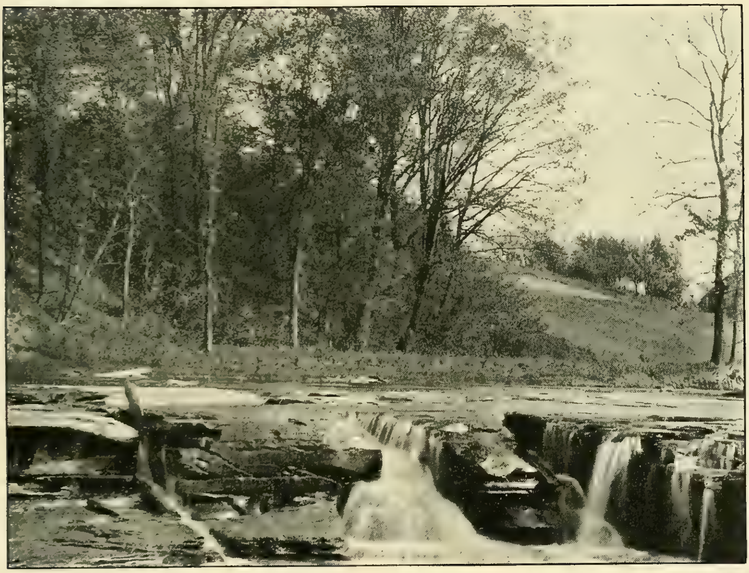


F. Houghton, Photo.

FIG. 17. A typical Rhinestreet cliff, Eighteen Mile creek below Hamburg. Note large concretions.

The shale immediately about the large concretions bends about them following the contours of the concretions rather than the normal horizontal bedding plane of its bed. A few of the concretions contain fossils. Two in the Eighteen Mile creek cliffs contained huge fish remains. From one found by the writer were obtained the bones of practically the entire head of an immense Dinichthys.

Although the Rhinestreet and Cashaqua shales are totally dissimilar in appearance and constituents, their line of contact is indefinite. Seen in a cliff they show as two distinct and well marked bands, but when closely examined they are found to merge. The transition from the gray Cashaqua to the black Rhinestreet is gradual through a foot or more of brown shale. At many points this brown shale is highly pyritiferous and marks the contact by a rusty, ironstained band. This band is frequently fossiliferous.



F. Houghton, Photo.

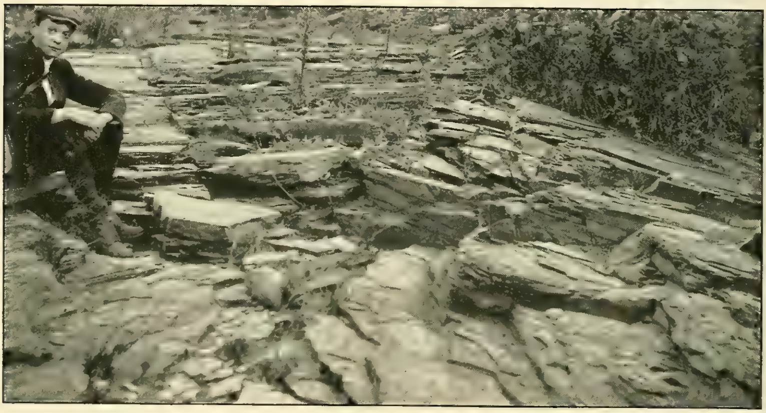
FIG. 18. Uppermost layer of Rhinestreet shale, Cazenozia creek, at Quaker Road bridge.

The contact of the Rhinestreet with the overlying Angola shale is equally indefinite. These merge into one another through recurring alternations of black and gray shales. I have considered as the topmost layer of the Rhinestreet a hard black layer capped by a layer of very large irregular flat concretions set together so closely as to form a practically continuous bed. This layer can best be seen in Cazenovia creek just above the

Quaker Road bridge where it forms a cascade across one branch and a rapids across the other. Yet the shales for twenty feet above contain huge concretions, though they are gray.

The Rhinestreet is exposed along the lake shore southward from Sturgeon Point as far as Dibble Bay, where the layer of concretions marking the top of the formation crops out at water level. Its lower beds and its contact with the Cashaqua are to be seen in Pike creek east of the road.

The whole formation can best be seen in the gorge of Eighteen Mile creek. The lowest layers appear first at the top of the cliff below the railway bridges. The contact with the underlying Cashaqua is well shown at several points above and below the old mill and bridge a mile above the railways. From this point the cliffs and bed of the stream are cut in this formation, the harder black layers causing rapids in the stream. The banks for much of its course are sheer cliffs. At a point three miles above the railways the stream forks. Above this junction in the gorge of the north branch rows of immense concretions appear at intervals in the cliff, and at several points the stream bed is cumbered with them. The surfaces of layers exposed in the stream bed exhibit numerous plant remains. At the old McKee's mill a layer of large concretions crosses the stream and forms a fall.



F. Houghton, Photo.

FIG. 19. Fault in Rhinestreet shale, below Erie Railway bridge, south branch of Eighteen Mile creek.

In the south branch the layers of concretions are shown as in the other branch. Half a mile below the Erie bridge there is a fault on the south side of the stream. The hard black layer and the layer of concretions which I have considered the topmost layer of the formation crosses the stream at the bridge and just above it.

The formation is exposed in a long section in the south branch of Smoke's creek from the dynamite storehouse to Green Lake. The topmost layer of concretions crosses the stream just below the dam which forms the lake.

The whole formation is exposed in sections along Cazenovia creek from the middle of a small brook which joins Cazenovia creek a mile south of Spring brook to the Quaker Road bridge. Just above the bridge the creek forks and the topmost layer crosses just above the junction. The layers in the stream bed here show fine plant remains. Plates of Philolepis have been found here by the writer.

The formation extends in Buffalo Creek from East Elma bridge to Porterville.

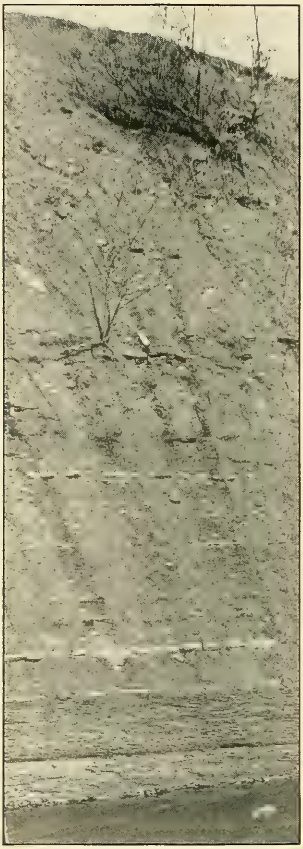
As a whole the Rhinestreet is not rich in fossils, yet some of the layers show a rich and varied fauna.

Angola Shale.

The Angola shale is that portion of the Portage beds lying between the black Rhinestreet below and the Hanover shale above. With the overlying Hanover shale it forms the Hatch shale. Originally it was included in the Gardeau. It was named from its exposure along Big Sister creek in the village of Angola, Erie County.

The formation comprises a series of light gray and fissile dark shales with frequent sandstone layers and concretions. It is 168 feet thick measured along Big Sister creek (Luther). Some of the lower dark shales are hard and black and resemble those of the Rhinestreet, though they are thinner bedded. Many of the concretions are small, usually not larger than a foot in diameter and frequently flat, but the lower beds contain concretions of large size, frequently four feet in diameter, resembling those in the Rhinestreet below.

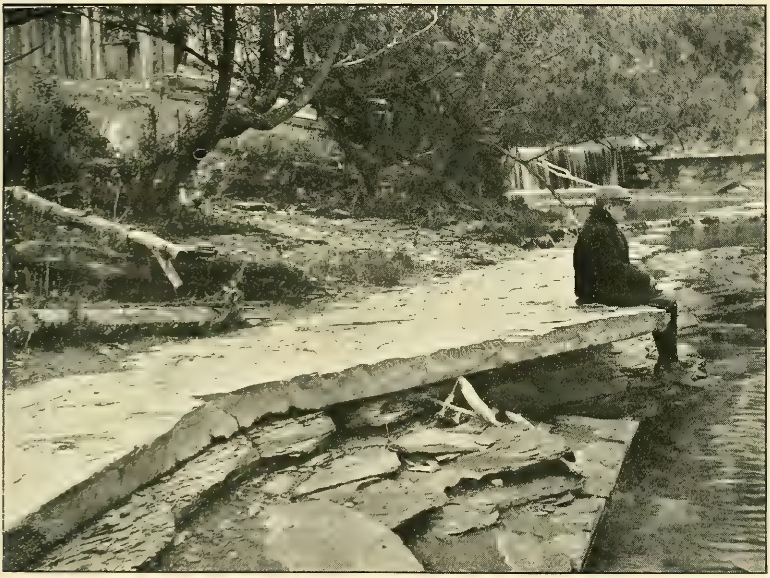
The constituents of the formation vary at its different exposures, the difference being mainly in the sand content. Thus the sandstone layers at Angola are thin but at Griffin's Mills on Cazenovia creek the formation includes six layers from six inches to a foot thick.



F. Houghton, Photo.

FIG. 20. Angola shale at Angola, showing gray shale and concretions.

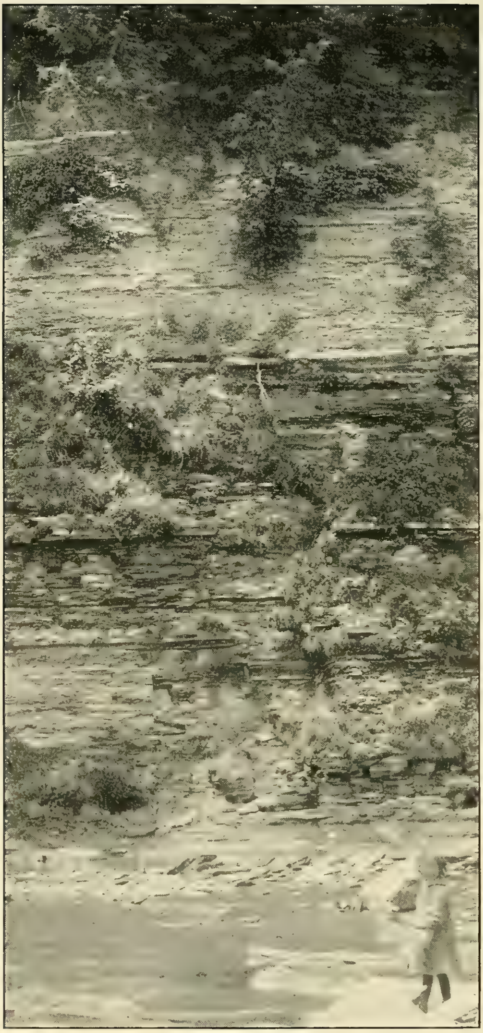
No definite line can be distinguished between the Angola and the overlying Hanover shale, and there seems little reason to subdivide the gray shales making up the two formations. I have arbitrarily fixed the line of contact below a layer of nodular gray shale about fifteen feet below a two foot black band which projects from the lake cliff just north of the mouth of Silver creek. This is unsatisfactory, however, as it is the only exposure of this layer in the county. Luther (p. 1024 Rept State Pal. 1902) describes a black layer four feet above a gray nodular layer and seems to consider this the top of the Angola. There is really nothing to distinguish one from the other. If the Angola and Hanover shales are in the horizon of the Hatch shales of Canandaigua, this name should be retained.



F. Houghton, Photo.

FIG. 21. Sandstone ledge in Angola shale, Griffin's Mills, Cazenovia creek.

The type exposure of Angola shale is in the cliffs of Big Sister creek from the cemetery at Angola to Pontiac. There are numerous exposures along the south branch of Eighteen Mile creek from the Erie railroad bridge to a point well beyond the State Road, and in a small gully debouching into the creek just above the Erie railroad. A fine exposure begins at the junction of the two branches of Cazenovia creek and extends upward beyond Griffin's Mills. The beds in detail may be seen in a small gully running from the west into Cazenovia creek at the bridge south of Jewettville.



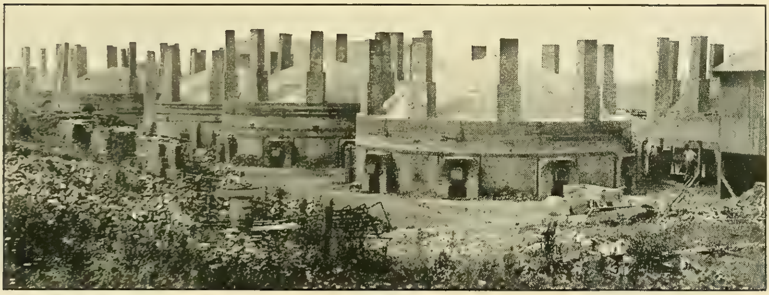
F. Houghton, Photo.

FIG. 22. Angola shale at Griffin's Mills, Cazenovia creek. Note the sandstone layers.

The Angola shale contains few fossils. In the beds exposed along Cazenovia creek plant remains are numerous. The beds immediately above the top of the Rhinestreet contain numerous nodules of pyrite which appear to be casts of fossils. The flattened concretions found in the middle of the formation at Angola contain fossils of a few species.

Shale of this formation has been used for the manufacture of brick and other clay products. The Buffalo Sewer Pipe Company has a plant on the Lake Shore Railway just west of Angola which utilizes this shale.

The Jewettville Brick Plant Number Two utilizes shale probably of this formation. It is situated a mile southeast of Orchard Park station on the Buffalo, Rochester and Pittsburgh Railway.



F. Houghton, Photo.

FIG. 23. Brick kilns utilizing Angola shale, Orchard Park.

The Ellicott plant, and the Jewettville Number One, at Jewettville, and Smith's yard at North Boston are all in this or the lowest Hanover beds.

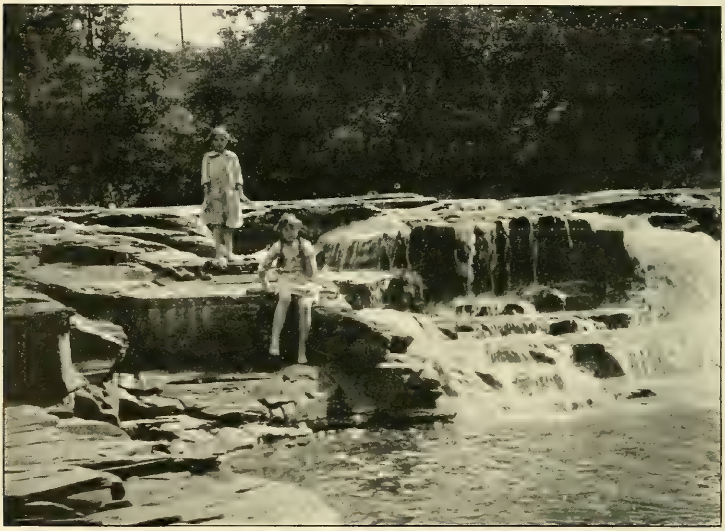
Hanover Shale.

The name Hanover shale has been applied to the upper portion, 112 feet thick, of a mass of 280 feet of gray shales and sandstones lying between the Rhinestreet shale below and the Dunkirk black shale above. The lower 168 feet of these have been given the name of Angola shale already described.

The upper or Hanover shale was at first designated the Silver Creek shale because of its outcrop at the village of Silver

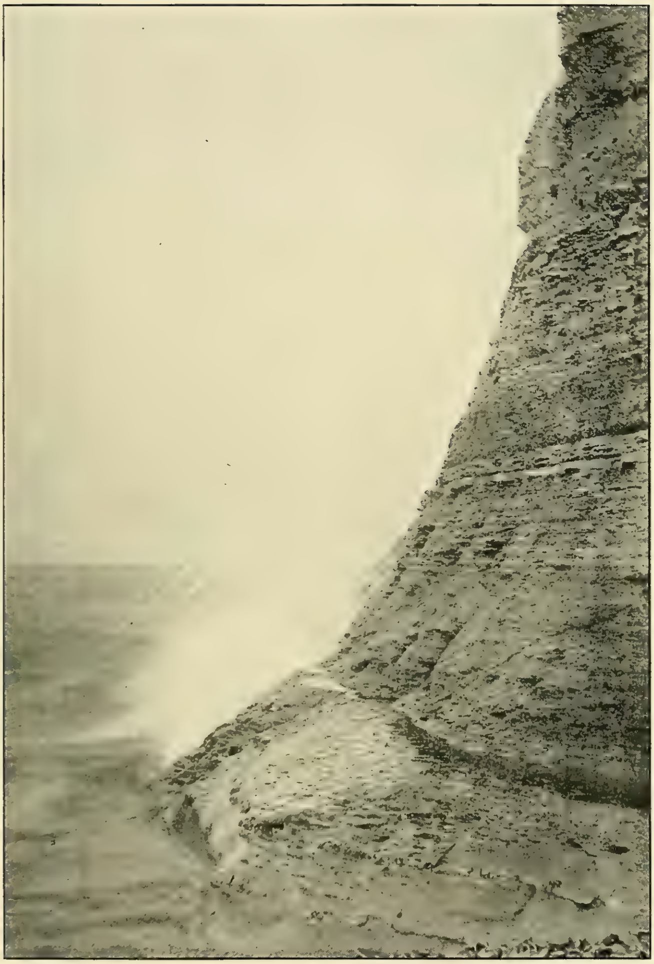
Creek, Chautauqua county. This name was found to be preoccupied and was changed to Hanover shale because of its exposure along Walnut creek in Hanover township, in which Silver Creek is also situated.

The formation is composed mainly of light gray shales with occasional sandy flags. It includes three black bands. One near the bottom is two feet thick. Two others in the lower half of the formation are each from ten to fifteen feet thick. The gray shale is characterized by a heavy bedded appearance. It is not fissile and does not break readily into laminae. Numerous layers are composed of gray unlaminated shale filled with small nodules which may range in size from an inch to two inches or more in diameter, and in shape from spheroidal to irregular. These nodular layers are hard and resistant and where they are exposed at the level of the lake, form a projecting shelf. In streams they form rapids or cascades. One such layer forms a shelf at water level along the lake from Silver Creek to Havilah. The three black layers are crossed by strong cleavage planes which cause their surfaces to take on the appearance of a tessellated pavement. The surfaces of these layers show plant remains.



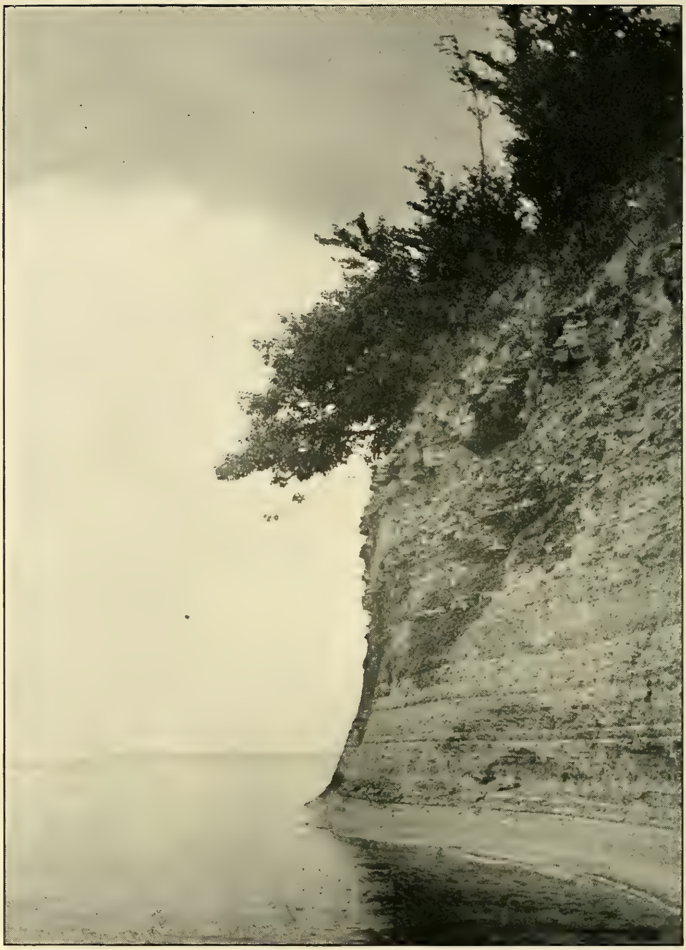
F. Houghton, Photo.

FIG. 24. Band of black shale included in the Hanover shales, Cazenovia creek, above West Falls.



F. Houghton, Photo.

FIG. 25. Cliff of Hanover shale, Lake Erie, south of Silver Creek. Note the resistant shelf of nodular shale at water level.

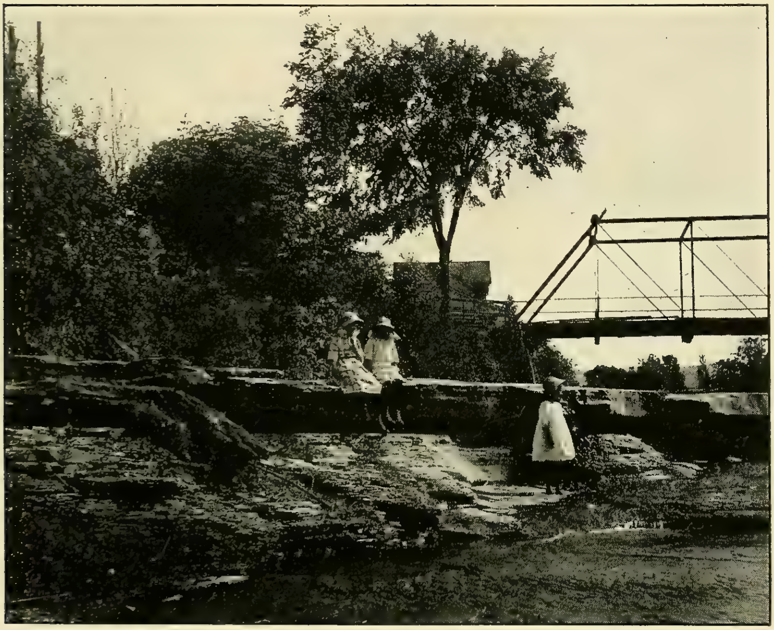


F. Houghton, Photo.

FIG. 26. Hanover shale, Lake Erie, north of the mouth of Silver Creek. The lowest black band is seen projecting from the cliff near its top.

The line of contact of the Hanover shale with the overlying Dunkirk shale is well shown at the mouth of Big Indian creek which joins Cattaraugus creek in Cattaraugus county below Iroquois. No line can be drawn between the Hanover and the underlying Angola.

The Hanover shale forms sheer cliffs along Lake Erie from Silver Creek nearly to Dunkirk. Fine exposures are to be seen in the valley of Walnut creek from Silver Creek to the bridge south of Hanover Centre. The contact of the Hanover with the overlying Dunkirk shale is seen at the mouth of Big Indian creek. At North Collins it is exposed in two gullies east of the state road. In the south branch of Eighteen Mile creek it is well shown. The formation begins east of the state road at Eden Valley and forms the bed and sides of the stream to a point half a mile north of Clarksburg. The lower of the two thick, black beds included in the Hanover, forms a high cascade at



F. Houghton, Photo.

FIG. 27. Sandstone ledge in lower Hanover or upper Angola shale, West Falls, Cazenovia creek.

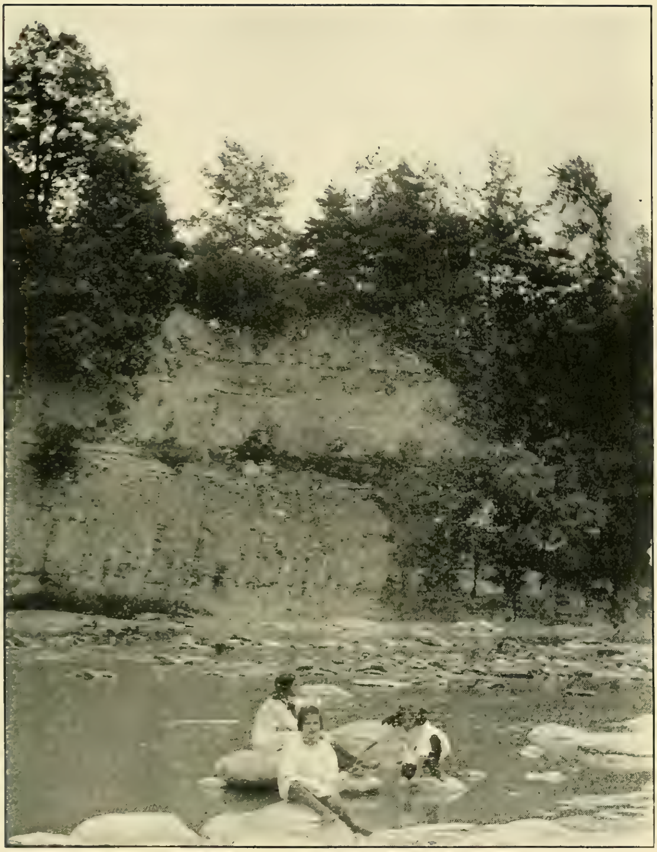
Toad Hollow. The upper of these two beds crosses about half a mile farther upstream and the contact with the Dunkirk shows at a small cascade on the east side of the road before turning to Clarksburg. There is a pronounced fault at this point. An excellent exposure occurs in a small gully running east from the state road two miles south of North Boston, and another is in Grace's gully three miles south of Orchard Park. In the Grace gully the contact with the Dunkirk is shown as well as the two black bands. This gully follows a long fault. The Hanover forms the cliffs along Pipe creek which joins Cazenovia creek above West Falls, and forms the bed of the creek from West Falls to the bridge above Pipe creek. The lower black band forms a cascade just below the bridge and the gray nodular shale forms another immediately below it. The cascade at West Falls is formed by a ledge of sandstone 16 inches thick, capping a series of gray shales the lower layers of which are hard and nodular. This seems to be part of the Hanover shale.

Fossils are rare in the Hanover shale. Plant remains are to be found in the black bands in abundance. I found one orthoceras in the nodular shale at West Falls.

Dunkirk Shale.

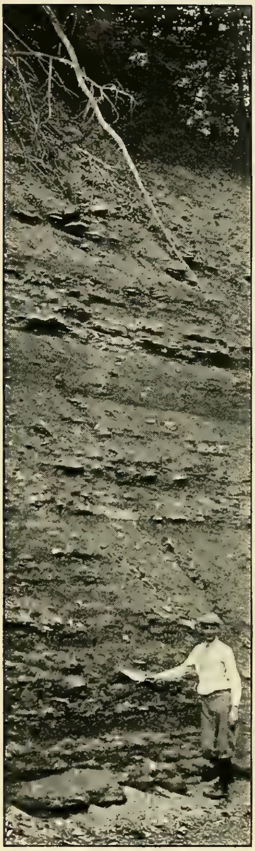
Bedded in the gray shales above the Rhinestreet black shales are four other black bands three of which have been included in the Hanover and the description of which is to be found in the preceding pages. The fourth band is of sufficient thickness to warrant giving it a name. It crops out at Dunkirk, Chautauqua county, hence has been designated the Dunkirk shale.

The Dunkirk shale is a deposit of black shale fifty-five feet thick, overlying the Hanover shales beneath. Hartnagel includes it in the Gardeau shale as its basal member. It extends beyond the eastern boundary of the county and seems to be represented in the Genesee valley outcrops by a band of rusty, black shale and thin flags exposed in the cliff at Wolf creek. These are the Grimes sandstones. It has all the characteristics of the Rhinestreet shale. It shows alternation of dense, black shale and fissile, black shale with iron stained laminae. A row of large concretions occurs near the middle of the formation. The upper part is crossed by numerous thin, sandstone layers the thickest of which is twelve inches thick and several of which are between six and twelve inches thick.



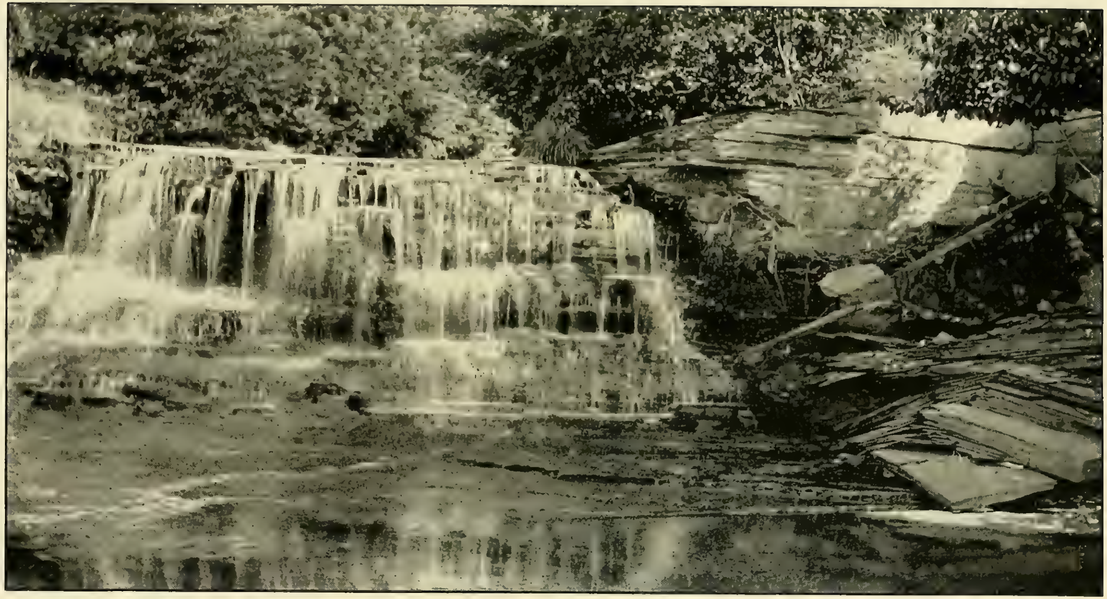
F. Houghton, Photo.

FIG. 28. Cliff of Dunkirk shale, Versailles.
The layer of large concretions crosses Cattaraugus creek at this point.



F. Houghton, Photo.

FIG. 29. Junction of Dunkirk shale and Gardeau shale. The boy stands on black Dunkirk shale. Above him are pink Gardeau shales.



F. Houghton, Photo.

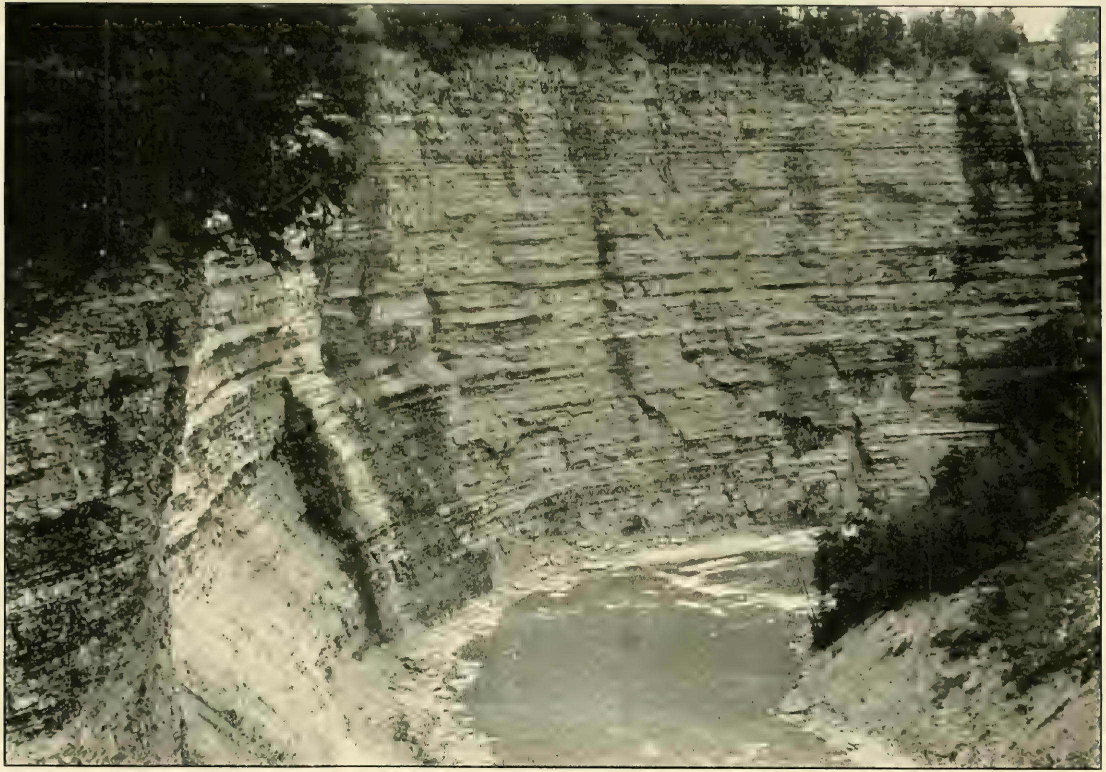
FIG. 30. Contact of the Dunkirk shale and Hanover shale, Cattaraugus creek, at the mouth of Big Indian creek. The Dunkirk is the dense, black bed at the right. The Hanover is at the base of the cascade.

No line of contact can be distinquished between the Dunkirk shale and the Gardeau shale above. They merge gradually, the transition in Big Indian creek being through a succession of thin, black layers, alternating with light gray, iron stained layers.

The Dunkirk shale forms the cliffs along the southern and western sides of Dunkirk harbor and the cliffs west of Point Gratiot. The whole formation is exposed in Big Indian creek and in the cliffs along Cattaraugus creek at Versailles. The exposure in Big Indian creek begins just below the bridge on the Hanover Center road in an alternation of thin, black shales and gray shales, above which are pinkish shales of the Gardeau formation. Below these transition shales appear beds of black, hard shales with strong cleavage planes and these continue downward with alternate beds of more fissile black shale and thin sandstones. The thickest of these forms a cascade fifteen feet high. The contact of the Dunkirk and Hanover is exposed at the mouth of the creek. Here the lowest bed of the Dunkirk is a mass seven feet thick of hard, black shale iron stained after exposure and splitting into very large, thin laminae. Underlying this is a bed of olive gray shale containing nodules the size of a pigeon's egg or smaller. This breaks into lumps rather than into laminae. As this nodular shale occurs throughout the Hanover shale there seems no doubt that this bed constitutes the upper bed of the Hanover.

The Dunkirk shale is exposed in a gully that runs eastward from the state road at North Collins. It forms a cliff along the southern branch of Eighteen Mile creek just north of Clarksburg. It crops out at the heads of the gullies east of North Boston, and forms a fall at Colden on Cazenovia creek. The concretionary layer is at the lake level at Van Buren Point, crosses Big Indian creek, causes a rapid in Cattaraugus creek at Versailles and shows in the cliff at Colden.

No fossils have been described from the Dunkirk shale. Plant remains are abundant in all its exposures.



F. Houghton, Photo.

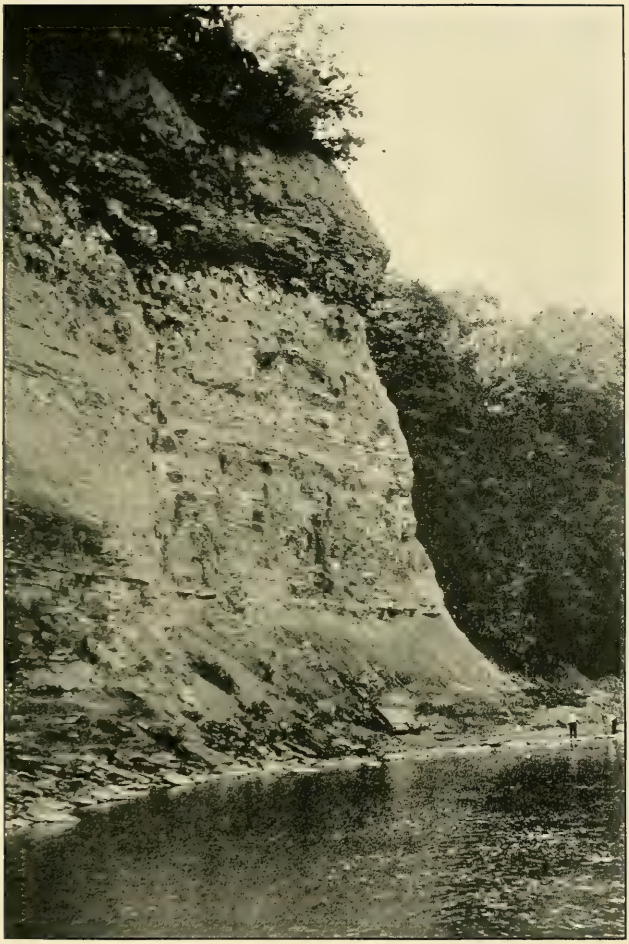
FIG. 31. Gorge of the Genesee river at Glen Iris, between the middle and lower falls. The cliff is of Gardeau shales and flags.

Gardeau Shale.

Lying in the upper Portage beds and limited below by the Dunkirk shale is the thick mass of the Gardeau shales. They have derived their name from their exposure at the former Indian Reservation at Gardeau on the Genesee river. Originally the name was applied by Hall to that portion of the Portage group lying above the Cashaqua shale and below the Portage sandstone. This great mass of rock has been subdivided by Dr. Clarke and the name Gardeau restricted to those shales and sandstones in western New York lying below the Laona sandstone, and in the Canandaigua exposures, limited below by the Grimes sandstones which seem to be the eastern extension of the Dunkirk. In western New York there is no definite line of demarcation at the bottom of these formations unless it be the Dunkirk shale. But Hartnagel in his classification of the rock formations has included the Dunkirk in the Gardeau. This makes the Gardeau in western New York include all the arenaceous and black shales and sandstones lying between the bottom of the Dunkirk shale and the Laona sandstone. The Dunkirk shale is distinct enough to warrant our excluding it from the Gardeau.

The Gardeau shale thus defined, excluding the Dunkirk shale which has been described in previous pages, comprises a thick deposit of sandy shales and thin sandstones of which Luther described 350 feet in Walnut creek, Chautauqua county. The formation includes layers of gray shale, without cleavage planes, not fissile but breaking into irregular lumps and usually stained brown on exposed edges. Other shales are black, fissile, and rust stained, with cleavage planes. Many beds are made up of alternating laminae of gray, sandy shale and sandstone. In a cliff the exposed shale frequently takes on a pink or red tinge. The sandstones are in thin layers from a fraction of an inch to a foot in thickness. Concretions are numerous and in some beds of rather large size.

The Gardeau shale forms cliffs along Cattaraugus creek from Versailles to Springville. A typical section may be seen in the cliff about three miles above Versailles. Some excellent sections are exposed at Gowanda and just above at the mouth of a small brook that joins the creek from the south. Another excellent section may be seen in the south branch of Cattaraugus creek about three miles south of Gowanda on the road to Otto. The



F. Houghton, Photo.

FIG. 32. Cliff of Gardeau shale, Cattaraugus creek between Gowanda and Versailles.

lower beds and their contact with the Dunkirk shale are shown in Big Indian creek. A small gully opening into Cazenovia creek from the west at Glenwood shows about two hundred feet of Gardeau. The upper beds are seen in the numerous gullies opening into the east branch of Cazenovia creek from the east, between Blakely and Holland, and in the gullies opening into Buffalo creek between Wales and Java. Johnson's Falls just outside of Erie county, north of Strykersville, is in upper Gardeau and Laona sandstone. The fall, which is about 45 feet high, is capped by a layer of hard, compact, blue sandstone five feet thick, below which are gray shales showing cleavage planes, thin layers of black shale with cleavage planes, gray shale with nodules, and thin sandstone layers. In the face of the fall there are five of these sandstone ledges from a foot to three feet thick:

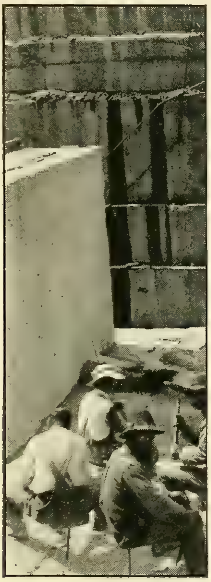
The Gardeau shales are moderately fossiliferous. Some of the sandstone layers near the top contain sponges. Luther reported finding "the common Portage fossils in small numbers" at Johnson's Falls, and further says that crinoids and aulopora also occur. He further reports that at Brocton cephalopods and large lamellibranchs occur in concretions.

Laona Sandstone.

In the Genesee valley the Gardeau formation is terminated by a thick mass of sandstone which is quarried under the name of "bluestone" at Portageville. It is a fine grained, compact, blue-gray sandstone lying in beds often fifteen feet thick which are separated by thin seams of shale. This has been designated the Nunda sandstone. In western New York this heavy bedded sandstone is absent and the top of the Portage is of consequence indefinite. A layer of sandstone twenty-two feet thick at Forestville is considered to be in the horizon of the bottom layers of this Nunda sandstone. This has been designated the Laona sandstone from its exposure at Laona, Chautauqua county.

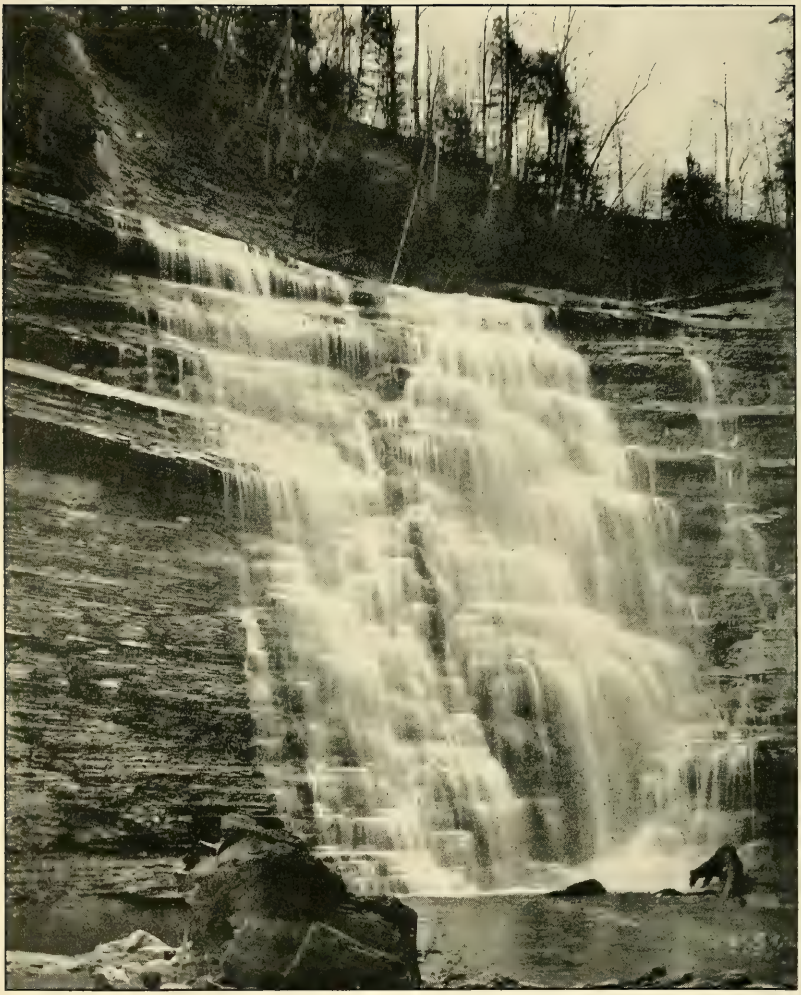
All the upper beds of the Gardeau exposed in Erie county show an ever increasing sandiness. The layers of sandstone grow more frequent and thicker as the upper beds are reached until they culminate in a series of beds from two to five feet thick scattered through a vertical distance of a hundred feet. Luther has ascribed some of these to the Laona sandstone. It is, however, very difficult to make any distinction between a possible Gardeau sandstone and a possible Laona sandstone.

The gullies opening into the east branch of Cazenovia creek, above South Wales and into Buffalo creek above Wales show excellent exposures of the sandstones which may possibly be referred to the Laona horizon. At Holland, east of the village, there is a long series of shales and sandstones of the Gardeau formation. The shales are gray, non-fissile, breaking into irregular lumps without cleavage planes. Interbedded with these are beds of dense, black shales with cleavage planes. Sandstones occur in heavy beds forming cascades and these are separated by beds of shale. The exposure at South Wales, is similar. In both, the uppermost sandstone is succeeded by shale identical in all respects with those below the sandstones. To all appearances these sandstones are identical with the thinner layers interbedded in the formation of lower down, and there seems little reason to consider them a distinct formation.



F. Houghton, Photo.

FIG. 33. Bluestone quarry at Portageville, in the Nunda sandstone. Note the great thickness of the beds.



F. Houghton, Photo.

FIG. 34. Johnson's Falls near Strykersville. The sandstone layers shown are probably in the horizon of the Laona sandstone.

Wiscoy Shale.

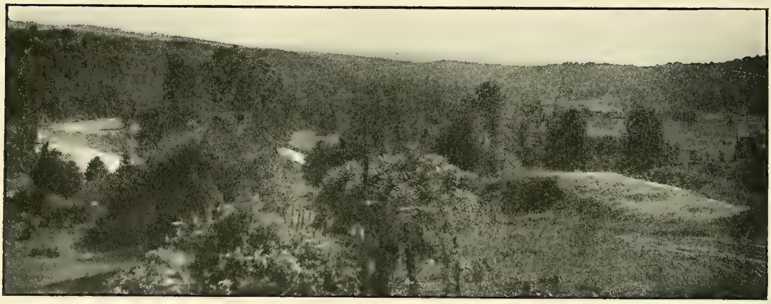
Lying above the Nunda sandstone in the Genesee Valley is a mass of shale named after the exposure in Wiscoy creek. This is limited definitely below by the heavy Nunda sandstone. In Erie county the Laona sandstone is indefinite. Above its probable horizon and therefore in the horizon of the Wiscoy are shales similar in all ways to the Gardeau. So much do the shales and sandstones of these three formations merge that no lines of demarcation are to be distinguished.

The shale lying above the possible Laona sandstone can be seen in the heads of the gullies east of Holland and above Johnson's Falls north of Strykersville. The shales outcropping at the south eastern corner of the county in the headwaters of Cattaraugus creek must belong to this formation. They can be seen at Yorkshire Center.

Post-Portage History of Erie County.

For Erie county the time following the close of Portage time was a period of slow upheaval. Whether our rocks were above the sea at the time of the deposition of the Chemung rocks can not be said. They probably were above water during the Carboniferous in common with the formations to the southward. The mountain making which marked the end of the Paleozoic seems to have affected them but little, though their permanent emergence above the sea probably occured at that time. Of the life that must have flourished on this new born land we have no record.

The time following the emergence of the land from the sea has been a time of destruction. The various agencies of subaerial erosion began their attack upon its newly emerged rocks. Waves beat upon its edges. Frost and rain rent asunder and dissolved the rocks. Streams began their appointed work of degrading the new land to the level of the sea. But of this erosion we have little record. Some of the valleys now occupied by our streams were undoubtedly eaten out by the rivers of that time. The topography of the county has changed materially since, yet its main features exist now as they existed then. The valley of the Cattaraugus was eroded prior to the advance of the great ice sheet. Tonawanda creek was also entrenched in its present valley before glacial time and Buffalo creek is the dwindled successor of a river which during Mesozoic time carved a wide valley through the soft Portage and Marcellus shales of Erie county. The great lake at our doors probably did not exist at that time. If it were in its present location it was at least different in its aspect. Probably its present bed was the valley of a great river which received the waters of what is now the upper Allegheny river and carried them northwards to the valley where is now and perhaps then was the great Lake Ontario. On the south the hills, our hills, of Erie county reared their heads as now. The "Ledge" looked then much as it does to-day.



F. Houghton, Photo.

FIG. 35. Valley of Cattaraugus creek below Springville. This was eroded before the Glacial Age, perhaps in Mesozoic time.

Although the main features of the county remain as they were in the Mesozoic, they have been changed in detail. Ages of erosion have flattened the hills and widened and deepened the valleys. These hills and valleys were later buried from sight for countless ages under a great ice sheet and when they finally emerged from their icy prison they were everywhere mantled and clogged with the debris of glaciation. Our gorges and falls are the result of new valley-cutting by streams whose old valleys, widened and flattened through long eras of erosion, had been dammed and filled with drift. Even our great Lake Erie is but the dwindled successor to the greater bodies of icy water derived from the melting away of the ice sheet.

The glacier which so changed the topography of our county was the southern extension of an immense continental ice sheet which, during the Pleistocene, formed in the region about Hudson Bay and spread thence radially over a vast tract from the Arctic ocean to northern Pennsylvania and from the Atlantic ocean to the Rocky mountains. The appearance of the northern part of our continent at that time would have been identical with that of Greenland to-day. This is still covered with an ice sheet, the shrunken remainder of the great glacier which uncounted thousands of years ago covered our county from view.

The causes of the formation of this enormous sheet of ice are unknown. To form such a glacier it would be necessary so to change the climatic conditions of the northern part of North America that the snow-fall of winter could persist through the following summer. The cooling of an area of this size to a point necessary for snow to persist through twelve months has been ascribed to various causes. The slow swing of the earth's axis in the precession of the equinoxes, or the elevation of the entire area above the snow line would have been effective.

The thickness and weight of the mass must have been enormous. In Erie county we have no measure of its maximum thickness. Gravel beaches at Springville were formed by a lake of water penned into the Cattaraugus valley by the ice of the retreating glacier. The lake marked by these beaches drained southward through a channel at Machias at an elevation of 1646 feet. The lowest point of the ice front therefore at this stage of its retreat must have been more than 1646 feet above the sea or approximately 1500 feet above the bottom of the depression now occupied by Lake Erie. Certain hills in Allegheny county show no signs of glaciation above the 2200 foot contour. This seems to mark the highest point of the ice sheet at its southern limit. There seems little doubt that the site of Buffalo was covered with ice to the depth of at least 1500 feet.

The southward extension of the glacier was due, no doubt, not so much to the existence here of a climate colder than our present climate, as to the immense weight of the semi-plastic mass. This spread outward from its center just as half-cold coal-tar will spread on a pavement. The enormous weight of the ice at the north pressed outward the lower lying layers and the whole mass thus spread imperceptibly but persistently.

Effects of Glaciation.

The action of the glacier upon the land which it overrode may be classified as follows:

Erosion by ice.
Deposition by ice.
Erosion by streams fed by glacial waters.
Deposition by these streams.
Erosion by the waves of lakes held in by the glacier.
Deposition in or by glacial lakes.

Erosion by the Glacier.

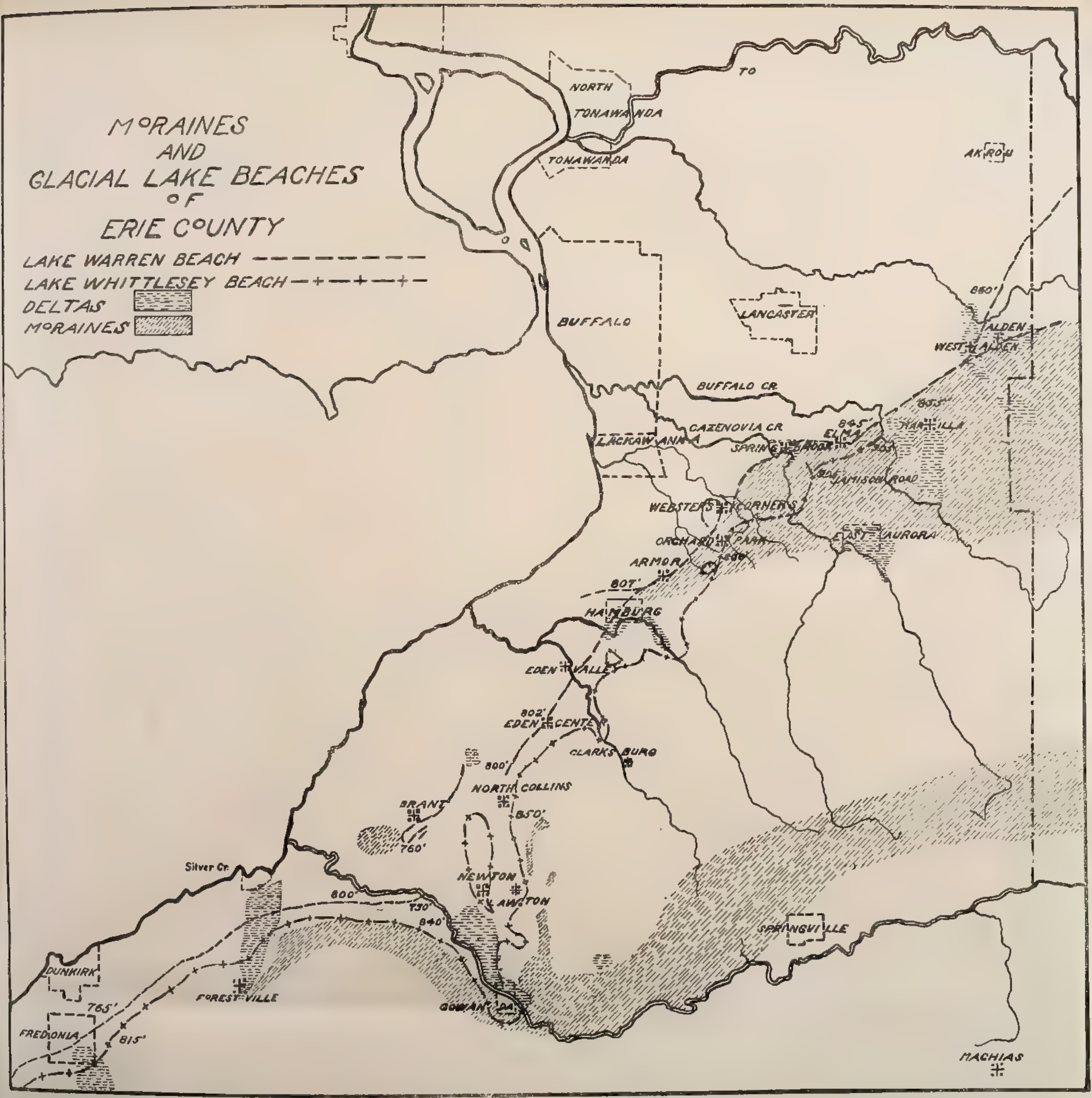
The tremendously heavy mass of ice dragging slowly over the surface of the land acted upon the land beneath exactly like a plane. Imbedded in its bottom were rocks, pebbles and sand which, as they were dragged along a land surface, scored, scratched and polished hard rocks and deeply eroded the softer shales. Where the motion was at right angles to slopes the ice tore away the northward fronting slope, but rode smoothly down the southward slope with little erosion. When the movement was parallel to the slopes, as in the valleys of north and south streams, the glacier may have widened and deepened them, by erosion at the bottom and sides.

In Erie county the erosion by the ice is plainly shown on the surfaces of outcrops of Onondaga limestone. Wherever flat exposures of this are exposed by streams or excavations the surfaces are found to be planed smooth or scored deeply with parallel striae, the work of the sand and gravel imbedded in the glacier.

Transportation and Deposition by the Glacier.

The detritus derived from the scouring action of the ice upon the surface underlying it was transported sometimes to long distances. Much of it was deposited as moraines along the ice front. Some was deposited under the ice as drumlins.

It is this deposition of detritus that so materially changed the topography of the county. The soil of all the county is primarily the result of this deposition and transported detritus has been left behind in such enormous quantities as to bury or


MORAINES AND GLACIAL LAKE BEACHES OF ERIE COUNTY
LAKE WARREN BEACH
LAKE WHITTLESEY BEACH
DELTAS
MORAINES
TO
NORTH
TONAWANDA
TONAWANDA
AKRON
BUFFALO
LANCASTER
860'
ALDEN
WEST ALDEN
BUFFALO CR.
855'
MARILLA
845'
CAZENOVIA CR.
ELMA
LACKAWANNA
SPRING BROOK
805'
JAMISON ROAD
WEBSTERS CORNERS
EAST AURORA
ORCHARD PARK
880'
ARMOR
807'
HAMBURG
EDEN VALLEY
802'
EDEN CENTER
CLARKSBURG
800'
NORTH COLLINS
BRANT
850'
760'
NEWTON
LAWTON
Silver Cr.
800'
730'
840'
SPRINGVILLE
DUNKIRK
FORESTVILLE
765'
GOWANDA
FREDONIA
815'
MACHIAS

partially obliberate even the most prominent of the features of the county.

The morainal tracts of Erie county are two in number. The first is an eastward extension of a great terminal moraine which first enters New York at the State line near Ripley. This lies parallel to Lake Erie and caps the prominent range of hills which is the divide between the lake and the Allegheny drainage. It enters Erie county at Gowanda and extends eastward up the Cattaraugus valley to the county line and beyond. In Erie county this morainal belt is widest in the town of Collins where it extends from Cattaraugus creek northward for a distance of perhaps two miles.

The second morainal belt first appears in the town of Brant in scattered patches of drift, thence extends north easterly through East Hamburg, Elma, Marilla, and Alden, and on out of the county towards Batavia. Its greatest width is attained in the towns of Marilla and Alden where it extends from Wales to Alden village.

At many points in the county are detached morainal deposits. A group in South Buffalo and Lackawanna at the city line and Abbott Road is typical of these, which were probably formed under the ice.

Both the morainal belts mark pauses in the recession of the glacier. Both are characterized by an undulatory surface dotted with sharp knolls and hillocks, and by a soil made up of the heterogeneous debris of glacier erosion. Boulders are scattered over the surface in profusion and lie thickly imbedded in the finely powdered blue and yellow clay which makes up the bulk of the deposits.

Erosion and Deposition by Glacial Streams.

The front of the glacier was the source of strong streams which derived their waters from the melting glaciers. In the earlier stages of glacial advance these waters undoubtedly followed the ancient drainage channels carved out by the preglacial rivers. But as the ice advanced southward it buried and clogged these and the water was forced to find new channels. At the time of the farthest advance of the ice when its front stood at Olean, the waters were led away southwards down the present Allegheny and Susquehanna rivers. At a later stage of its retreat when its front lay along the present morainal zone at Gowanda, the water was still prevented by the ice from taking its ancient course to the westward and was forced southward over the divide at Machias and Dayton, where are to be seen the great channels which carried the glacial waters southward to the Allegheny.

Subsequently when the ice had receded from its moraine at Gowanda and had paused once more at the point now marked by the Hamburg moraine the water had found a lower outlet than those at Machias and Dayton. The surface of Erie county slopes to the northward. The glacier was retreating slowly down these slopes. As a consequence there came to be an ever widening notch between the ice front and the uncovered land surface. This gradually widened into a v-shaped trough closely following on the north side the ice front and the southern side the emerging slopes of the land surface. This trough naturally filled with water from the melting glacier and a lake was formed, and into this lake were emptied not only the glacier streams but the drainage of the emerging land.

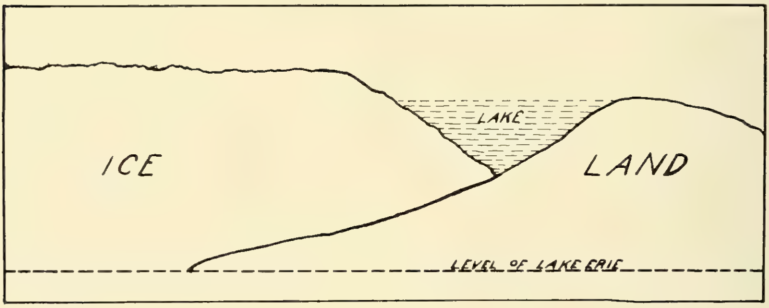


FIG. 36. Diagram showing how a lake was formed between the southward-facing glacier and the northward sloping land of Erie county.

At this stage the entire southeastern half of the county had emerged from its ice covering. Its ancient stream channels were dammed at their lower ends by the ice and were consequently filled with water which extended far up their valleys. Each valley formed a separate little lake and each of these lakes drained into the next across the ancient divide at its lowest point. The lakes filling the valleys of Cazenovia creek and

Eighteen Mile creek drained through a channel which debouched into a glacial front lake at Hamburg. The lakes filling Buffalo creek drained through streams that debouched into the same lake at East Aurora.

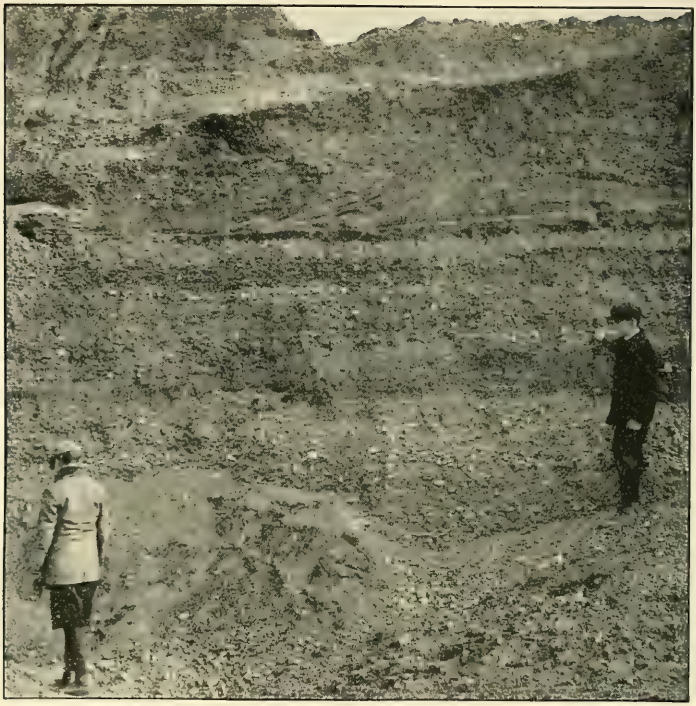
Several of these glacier front streams can still be traced in Erie county with reasonable accuracy. One of the best preserved is to be found southeast of Orchard Park. It heads in Cazenovia creek half a mile north of Quaker road, which it crosses in a southwesterly direction a mile west of the bridge at Jewettville. Thence it continues its course to Deuel's corners. Just southeast of Deuel's it is joined by a branch the bed of which is now occupied by the B. R. and P. Railway. South of Deuel's it continues its southwesterly course but loses its definiteness. It probably was the stream which built the delta plain upon which Hamburg is sitnated.

In its upper course, that is from Cazenovia creek to Deuel's, it is a well marked stream valley, now occupied by a tiny rivulet. South of Deuel's it loses one of its banks though the other side is well marked. The reason for this one sided valley seems to be that the stream at this point washed the edge of the glacier which served as one side of the stream.

Other glacier-front stream valleys may be seen in the moraine northeast of East Aurora and north of Wales. These seem to have flowed westward into the large glacial Lake Warren.

Glacial Lakes.

When the glacier had receded north of the divide between the Allegheny drainage and the present Lake Erie drainage a lake was formed in the trough between the ice and the divide. This lake overflowed at the lowest point in the rim of the trough. This lowest point varied at different stages of the recession of the glacier, as successively lower points were uncovered. The earliest of these lakes in this county seems to have been that in the upper reaches of the Cattaraugus creek which were uncovered before the lower portion of its valley. This lake overflowed at Machias at an altitude of 1646 feet and its outlet occupied the valley now occupied by Ischua creek. Its channel is strongly marked by huge sand and gravel beds. It drained into the upper Allegheny. A deep sand and gravel pit seems to mark a beach or bar of this lake just south of Springville at the top of a hill. It is formed of medium sized materials with well marked stratification.



F. Houghton, Photo.

FIG. 37. Beach south of Springville, probably formed by a lake which occupied the upper valley of Cattaraugus creek.

As the ice receded, a lower pass than that at Machias was uncovered at the head of the valley of the south branch of Cattaraugus creek. The consequent stream flowed southward over the divide at Persia at an altitude of 1300 feet and emptied into the Allegheny.

There finally came a time when the lowest edge of the trough which still existed between the northward sloping land and the southward facing glacier fell below the level of 1300 feet. Thereupon the waters which had been escaping over the divide at this level immediately overflowed at the lower levels which were successively exposed. These levels were lower than the divide between the Allegheny and Lake Erie and the waters were thus cut off from the Allegheny drainage and drained southwestward between the icefront and the divide. The successive lowering of the outlet was gradual with numerous stands which have been marked especially in the valley of the Cattaraugus by numerous wave formed plains, deltas and waterlevels. At Gowanda the series is as follows: (Fairchild)

Highest, southeast of Gowanda,	1210 feet.
Studley, south of Gowanda,	1032 feet.
Broadway, south of Gowanda,	972 feet.
Asylum level, north of Gowanda,	883 feet.
Collins plain, north of Gowanda,	855 feet.
The Four Mile level, west of Gowanda,	820 feet.

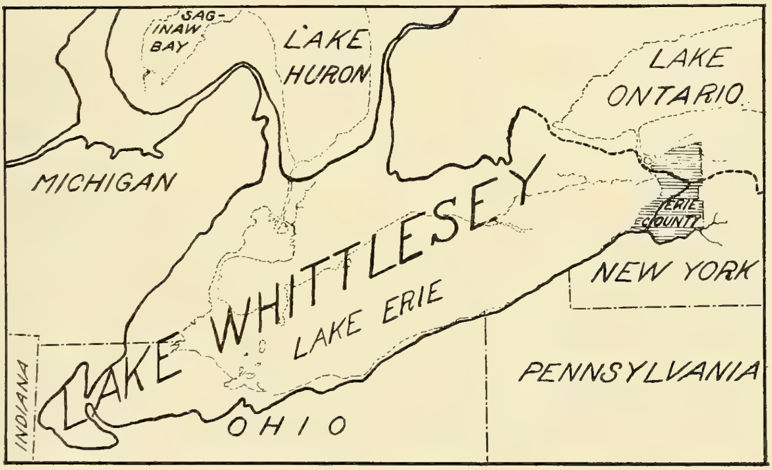


FIG. 38. The approximate extent of Lake Whittlesey, and its outlet to the westward. The shores of Lake Whittlesey are indicated by heavy lines, those of our present lakes by faint, dotted lines.

The lakes which formed these levels seem to have drained westward across northern Ohio and southern Michigan, thence southward to the Mississippi. Of these the last, in which was laid down the delta now known as the Four Mile level, has received the name of Lake Whittlesey. This can be traced by means of its beaches from the Pennsylvania line to Marilla.

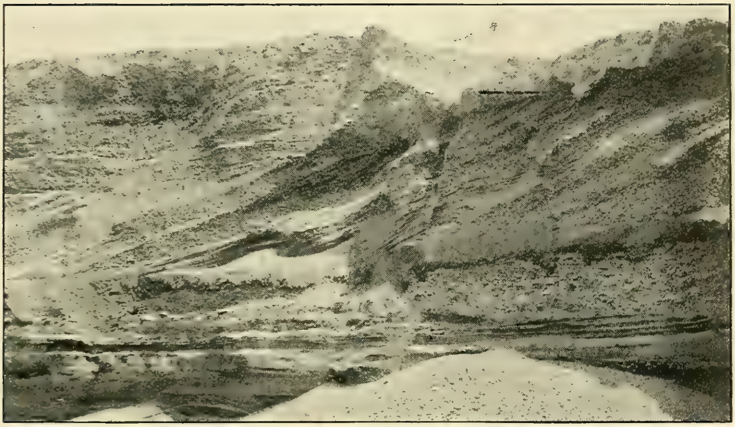
Lake Whittlesey, judging from the beaches still existent, covered that portion of Erie county northwest of an irregular line connecting Versailles on Cattaraugus creek with Marilla. Westward, the lake stretched as a long band across northern Ohio, its southern beach closely parallel to the southern beach of the present Lake Erie. South of Sandusky it spread westward to the Ohio line, thence northward to the neighborhood of Port Huron where it drained through a channel northwestwardly into a lake which drained into the Mississippi.

Its beach enters Erie county at Gowanda where it is a succession of deep gravel and sand beds. The top of one of these has been opened as a sand pit just above Gowanda at the edge of the road leading to Collins station. Another is open at the edge of the Erie Railway just at the northern edge of the village. It lies parallel to the Taylor Hollow road nearly to that point but curves eastward nearly to Collins station. From Gowanda to Taylor's Hollow it is a strongly marked ridge below which lies a flat delta plain, the Four Mile level. This level is a delta thrown into the lake at this point by the waters of Cattaraugus creek. It extends from Gowanda to Versailles. It is at all points a dead level stretch of sand and fine gravel. At Versailles its outward end shows a steep sand escarpment.

From Collins station the beach curves back to Taylor Hollow thence it follows the state road through Lawton and North Collins to Eden. It crosses the road twice in a sinuous curve at the north branch of Clear creek and again a mile north. At these points it is a strong sand ridge. From Clear creek nearly to North Collins it lies just east of the State road, which it crosses in a loop just before reaching the village.

North of the Council House on the Indian Reservation at Lawton is an island of this lake. At each end is a spit, the southern of which is a strong sand ridge on which stands the Council House.

From North Collins to Eden the beach lies east of the state road but beyond Eden it curves away to the east and crosses the south branch of Eighteen Mile creek at the end of the State Road just north of Toad Hollow. Thence it curves away in a general northeast direction and crosses the north branch of Eighteen Mile creek approximately at the line between Boston and Hamburg.

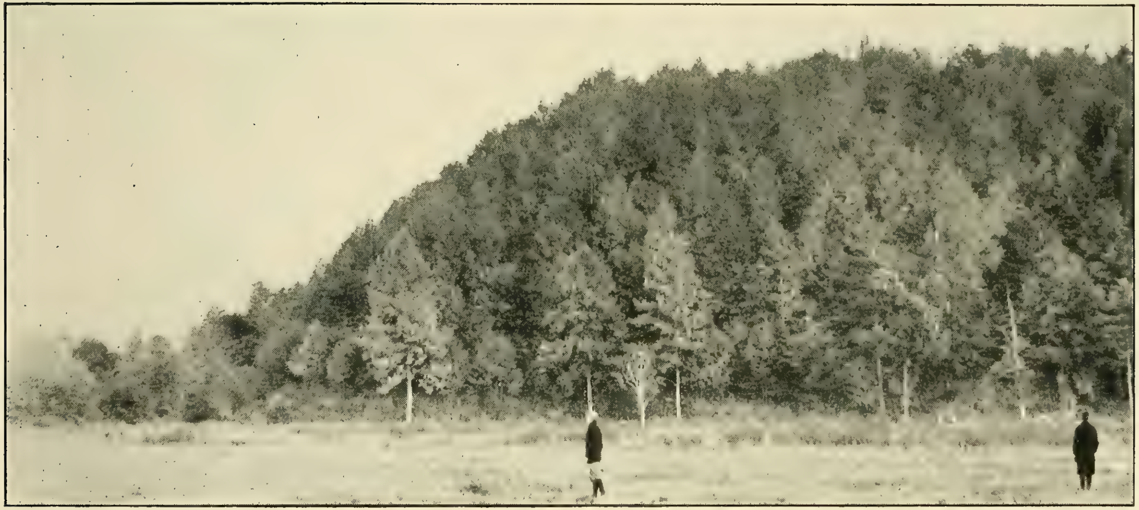


F. Houghton, Photo.

FIG. 39. Section of beach or bar, probably of Lake Whittlesey, north side of Cattaraugus creek at Gowanda.

F. Houghton, Photo.

FIG. 40. Beach of Lake Whittlesey at Taylor's Hollow.



F. Houghton, Photo.

FIG. 41. Western edge of the Four Mile level, at Iroquois. This is the outward end of a delta formed in Lake Whittlesey by Cattaraugus creek.

Just east of the junction of the two State roads south of Water Valley is an island with a strongly marked wave cut cliff on its northern face and a spit on its southeastern side.

The beach is to be seen east of the road from Armor to North Boston but grows indistinct in its northeastern course towards Orchard Park. Just south of Deuel's Corners is an island. In the southern edge of Orchard Park at the railway bridge is a strong beach which is probably this beach, and the ridge on which is the cemetery is undoubtedly this beach.

From Orchard Park northeastward to Marilla the beach is indistinct. It is probably represented by the ridge which carries the State Road at the corner of the Jamison Road, southeast of Springbrook, and the gravel beds at the top of the hill on the west side of Buffalo creek at East Elma probably belong to this beach.

Lake Warren.

At a level of 40 to 70 feet below the beach of Lake Whittlesey a series of beaches and bars marks the level of an extensive glacier front lake which has been designated Lake Warren. This lake was formed by the lowering of the waters of Lake Whittlesey when the receding glacier uncovered an outlet lower than that at Port Huron. The lake covered a strip of Erie county northwest of a line drawn from Versailles to Alden and limited northwardly by the ice front. Westward the lake extended across northern Ohio to a point on the Maumee river west of Toledo, thence north to Bad Axe in the northern end of the southern peninsula of Michigan and thence encircled Saginaw Bay. Its outlet followed the present course of Grand River to Lake Michigan. Eastwardly the lake lay in a narrow strip in the trough along the ice front as far as the present city of Auburn, with long narrow bays extending up the north and south valleys of the Genesee river and the Finger Lakes.

The shore line character varies at different points. From Versailles to Eden there seems to be but one beach, although immediately west of Cattaraugus creek there are two strongly marked beaches. It passes from Brant Center to Pontiac appearing at Brant on the farm of George Baron as a strong sand ridge.

It appears just west of North Collins and carries the State road from that village to Eden Valley and Hamburg.

At Hamburg it is complicated by delta formations. One strong beach or bar extends westward toward Wanakah from about where the State Road crosses the Erie railway. The main beach passes northeast from Hamburg to Orchard Park, bearing a road as far as Armor. North of Armor it is a well marked ridge as far as Orchard Park. Just north of Orchard Park it crosses the State Road twice, once just on the edge of the village, again at Webster's where it curves into a great fish hook bar.

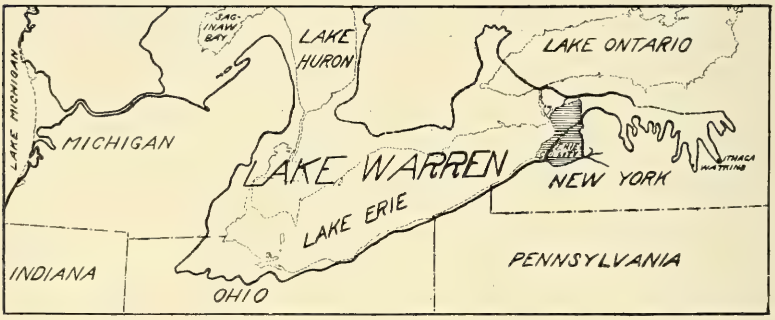
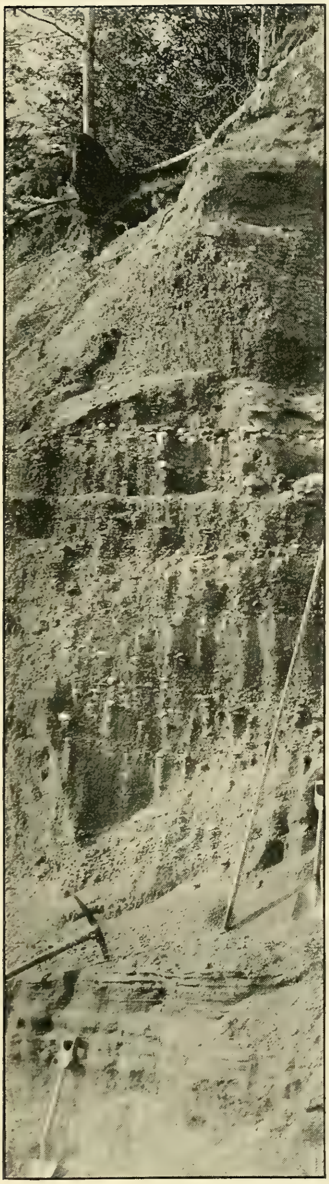


FIG. 42. The approximate extent of Lake Warren and its outlet to the west. The shores of Lake Warren are indicated by heavy lines, those of our present lakes by faint dotted lines.

An excellent section of this beach is seen in a gravel pit just east of Webster's. Thence it continues its northeasterly course as a ridge to Springbrook where it crosses Cazenovia creek a mile south of the churches. Thence it continues to Elma Center where it crosses the railway just beyond the station. At Alden two beaches appear. One of these continues to Indian Falls in Genesee county.

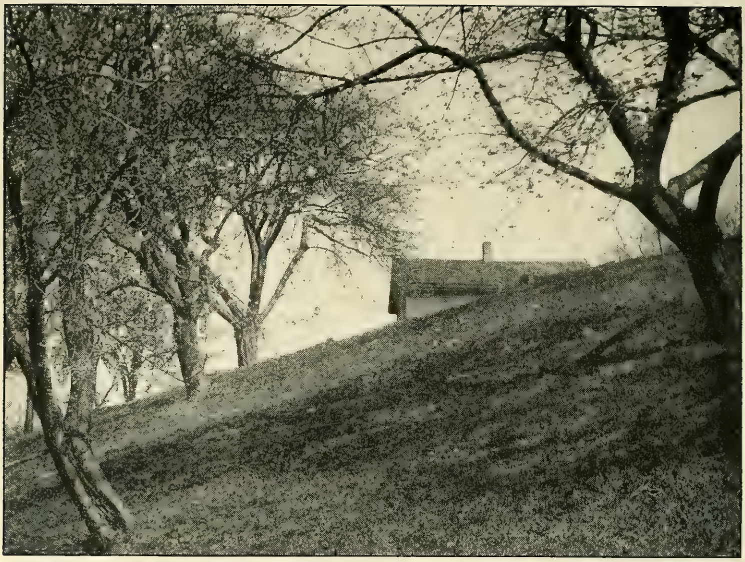
Lake Warren persisted until the glacier had so far receded as to uncover the low lying divide at the headwaters of the Mohawk river. Once these had emerged the waters of Lake Warren abandoned their higher outlet to the westward and drained off down the Mohawk.

There seem to have been successive stages in the lowering of the lake and successive stands in its level. None of these were of sufficient duration to form great beaches such as characterized their predecessors. Of these stages, one, the most strongly marked, has been named Lake Dana.



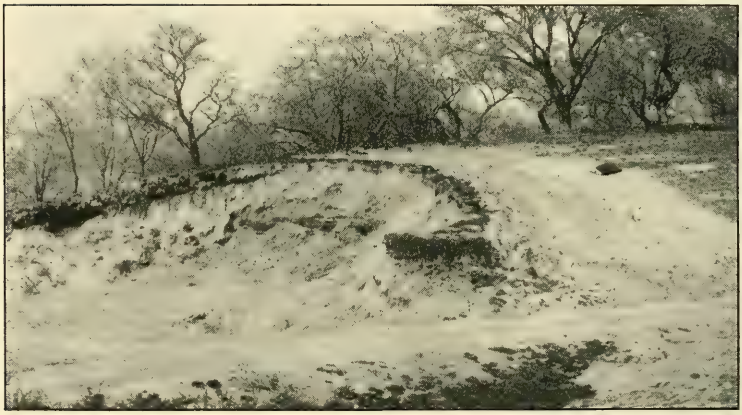
F. Houghton, Photo.

FIG. 43. Section of beach of Lake Warren, Webster's Corners. It ha been opened as a gravel pit.



F. Houghton, Photo.

FIG. 44. Beach of Lake Warren, south of Springbrook.



F. Houghton, Photo.

FIG. 45. Section of beach of Lake Warren, south of Springbrook. The excavation is a gravel pit.

In Erie county Lake Dana is marked by rather faint gravel and sand beaches following the 620 foot contour. The strongest encircles the ridge of till which bears the Ridge Road in Lackawanna. This ridge would have appeared as an island in the lake. Gravel pits have been opened along this ridge to the depth of fifteen feet. North of the ridge are two small till ridges which show wave cut terraces. The till ridge north of Ebenezer bears a gravel pit on its north side which is on this contour and, at the same level, sand beaches are to be seen on Utica street, Buffalo, and neighboring streets, and at Pine Hill just east of Buffalo.

Lake Dana was drained eastward through the Mohawk valley. It was lowered by successive stages when lower and lower channels were uncovered over the Mohawk divide.

The country now included in the northwest corner of Erie county remained under the water of Lake Dana until the level of its outlet fell below the level of the top of the Niagara escarpment, the Mountain ridge. Its successor below the Mountain ridge was Lake Iroquois which formed the beach that is now the Ridge Road running from Lewiston eastward across Niagara county.

With the gradual passing away of the great glacier from Erie county its present topography began to appear. Some of its ancient stream valleys had been filled and obliterated by deposits of drift. Some had been transformed into long, narrow lakes. The wide, sloping hills, the result of ages of erosion, had been covered deeply with glacial debris. Great lakes and glacial streams had left their beaches and bars high up in the hills. Glacial streams had eroded valleys and had built the debris into deltas in the lakes, and these were left after the recession of the waters as long, sandy, flat-topped plains. Stretching across the county were the great moraines left at the ice front and over all was a sheet of glacial till.

Since the recession of the ice sheet the agencies of sub-aerial erosion have been at work shaping the topography of the county. The melting away of the ice was followed by a gradual uplift of the land surface at the north and this uplift is still going on. The elevation of the land since glacial times can be easily measured by the differences of level in the beaches of the glacial lakes. These beaches, naturally, were laid down originally at the water level of these lakes. Measured by this level, the land of western New York has lifted upward to the north 122 feet from the Pennsylvania state line to Marilla, or measured in Erie county the uplift has been 55 feet between North Collins and Marilla, so that Marilla which was originally at the same level as North Collins has been elevated 55 feet above it. The rate of uplift is not the same everywhere but it increases toward the north. From the state line to North Collins it rises 67 feet in 48 miles or at the rate of 1.4 feet per mile. But from North Collins to Marilla it rises 55 feet in 26 miles or at the rate of 2.1 feet per mile. Outside our county this increase continues until at the east end of Lake Ontario it rises at the rate of 6 feet per mile. Southward and westward the tilting decreases until there is little or no deformation to be detected in northern Ohio on the Whittlesey beach. (Leverett, 755.)

There can be little doubt that this tilting of the land to the north and the masking of old drainage channels by glacial debris have contributed materially to the change of direction of flow of our streams. Before the glacial period the upper tributaries of the Allegheny seem to have flowed northward joining finally the waters of Cattaraugus creek and continuing westward into the depression now occupied by Lake Erie. The tributaries of the middle Allegheny also seem to have flowed north into the same depression. The glacier dammed these drainage channels and caused the Allegheny waters to seek a pathway southward. Aided by the enormous amount of glacial water derived from the melting of the ice, they found a course by reversing the flow in the upper Allegheny. This led them to the lower Allegheny and to the Mississippi.

Cattaraugus creek, deprived of its main southern tributaries by the reversal of the drainage south of the glacier, abandoned that portion of its valley lying between Zoar and Gowanda and since the glacial time has cut a new channel. From Gowanda to the lake it occupies its ancient channel but it has swung sufficiently in it to make rock walls at several points.

Eighteen Mile creek, which, before the glacier, had drained westward separately through the channels of its two present branches into the Lake Erie depression has been forced to cut a new channel, instead of excavating the drift-filled channels of its lower valley. The new channel of the west branch, little wider as yet than the stream bed, begins below Clarksburg and is cut through Portage shales to a point four miles west of Hamburg where it joins the new, narrow channel of the east branch which begins above Hamburg.

Buffalo creek and Cazenovia creek seem to have continued their course practically in their ancient valleys. These had been dammed by the glacier and long finger lakes had formed in the upper courses. These had drained in various ways but after the melting away of the glacier the streams resumed their old courses.

The great lakes which characterized the topography of Erie county during the recession of the ice sheet disappeared when the tremendous supply of water derived from the melting ice ceased. Our present Lake Erie is their shallow successor. It occupies an ancient preglacial depression. It is held as a lake only by the ledges of Onondaga limestone and Niagara limestone which form the lowest point in its rim. This lake may persist until the Niagara river has worn back its canon to a point where the Onondaga limestone dips beneath the lake bottom. At the present rate of tilting at the north this may never happen. The future of Lake Erie depends upon the relation in time between the rate of erosion of Niagara river and the rising of the Onondaga limestone across it by this uplifting process. This is further complicated by the result of this tilting upon the upper Great Lakes. These supply the water which is the main erosive agent of Niagara river. A continued tilting of the northern ends of the upper lakes must result in the abandonment of the Detroit river as an outlet and the resumption of the glacial channel across the low lying divide at Chicago. The abandonment of Detroit river will cut off the main water supply of Lake Erie and so reduce the erosive force of its outlet as to lengthen its life indefinitely.

The Fossil Content of the Rock Formations of Erie County.

Although the fossils of a few of the formations of Erie county have been subjected to detailed study by several observers many have received practically no attention from palaeontologists and there is a great opportunity for special students along this line.

In general the formations of Erie county are rich in fossil content. The limestones at the base of the section show a varied and peculiar fauna. The Hamilton beds are extremely fossiliferous and these are favorably exposed at numerous places in the county. The Genundewa limestone is the repository of an immense number of fish remains and although the Portage beds of the county are less fossiliferous than the earlier beds, even they contain a fairly abundant assemblage of fossils.

Owing to the presence in the Cobleskill limestone of the abundant Eurypterid fauna, this formation has been given much detailed study by numerous observers. The Stafford limestone has been minutely examined and its fossils described by Elvira Wood. Amadeus Grabau published as a bulletin of the Buffalo Society of Natural Sciences a careful study of the fossils of the Hamilton beds. The Genesee beds have been searched for fish remains by W. L. Bryant and the resulting description will doubtless soon be published. The remaining formations have received no such special study.

The Onondaga limestone is extremely fossiliferous but owing perhaps to the difficulty of freeing its fossils from their matrix there seems to have been no study made of those occuring in the county. Although Dr. Grabau examined and described the upper beds of the Cardiff shale, the remainder together with the Skaneateles remains practically untouched. The fauna of the Portage beds of Erie county is practically unknown. D. Dana Luther described these beds but only incidently mentioned their fossils. Dr. Clarke in his "Naples Fauna" describes fossils from Erie county but localizes them so indefinitely that it is impossible to place them accurately in their formations.

In the tables below I have endeavored to collect the names of all the fossils recorded as occuring in Erie county together with the formations in which they were observed. It is based upon the work of the following observers:

Cobleskill limestone, D. Dana Luther, Geology of Buffalo Quadrangle; Stafford and Marcellus shales, Elvira Wood, Marcellus limestones of Lancaster; Cardiff shale to Genundewa limestone, Grabau, Palaeontology of Eighteen Mile creek; Portage beds, J. M. Clark, Naples Fauna in western New York; the entire series, James Hall, Palaeontology.

	Camillus	Bertie	Cobleskill	Onondaga	Marcelles	Stafford	Cardiff	Skaneatel	Ludlowville	Tichenor	Moscow	Tully	Genesee	Conodont	Styliola	West River	Middlesex	Cashaqua	Rhinestreet	Angola	Hanover	Dunkirk	Gardeau	Laona	Wiscoy
HYDROZOA:																									
Dictonema hamiltoniae H.									+																
ANTHOZOA:																									
Streptelasma rectum H.						?			+		+														
S. ungula H.											+														
Zaphrentis simplex H.										+	+														
Amplexus hamiltoniae H.											+														
A. intermittens H.											+														
Heliophyllum Halli H.									+		+														
H. confluens H.										+															
Cystiphyllum conifolis H.									+		+														
C. americanum									+		+														
C. varians H.									+																
Cyathophyllum conatum H.									+																
C. hydraulicum			+								+														
Hadrophyllum woodi											+														
Craspedophyllum archiaci										+															
C. subcaespitosum Nicholson										+															
Favosites argus H.									+																
F. placenta						+			+																
F. hamiltoniae H.									+																
Pleurodictyum stylopora H.									+																
Aulopora serpens Goldfuss									+																
A. tubaeformis Goldfuss									+																
Ceratopora jacksoni Graubau						+			+																
C. dichotoma Grabau						+	+		+		+														
Trachypora limbata									+																
Monotrypa fruticosa H.									+		+														
M. furcata H.									+																
M. amplectens									+																
Trematopora furtalinea H.						+																			
Favosites (species)			+																						
CRINOIDEA:																									
Gennaecrinus nyssa H.									+																
G. eucharis									+																
Dorycrinus sp.									?																
Habrocrinus pentadactylus											+														
Platycrinus eriensis H.									+																
Taxocrinus nuntius H.									+																
Ancyrocrinus bulbosus H.									+		+														
Melocrinus Clarkei Williams															+										
Scytalocrinus ornatissimus H.																							?		?

	Camillus	Bertie	Cobleskill	Onondaga	Marcellus	Stafford	Cardiff	Skaneateles	Ludlowville	Tichenor	Moscow	Tully	Genesee	Conodont	Styliola	West River	Middlesex	Cashaqua	Rhinestreet	Angola	Hanover	Dunkirk	Gardeau	Laona	Wiscoy
ANNELIDAE:																									
Tubes:																									
Spirorbis angulatus H.									+																
Autodetus lindstroemi									+																
Conulites hamiltoniae Hinde									+																
CONODONTS:																									
Prioniodus erraticus														+											
P. abbreviatus														+											
P. clavatus											+			+											
P. angulatus													+												
P. acicularis													+												
P. armatus													+												
P. spicatus													+												
P. panderi														+											
P. alatus														+											
Polygnathus dubius											+		+	+											
P. nasutus													+												
P. princeps														+											
P. solidus														+											
P. crassus														+											
P. pennatus														+											
P. tuberculatus														+											
P. cristatus														+											
P. truncatus														+											
P. punctatus													+												
P. linguiformis														+											
P. palmatus													+												
P. (?) simplex														+											

	Camillus	Bertie	Cobleskill	Onondaga	Marcellus	Stafford	Cardiff	Skaneateles	Ludlowville	Tichenor	Moscow	Tully	Genesee	Conodont	Styliola	West River	Middlesex	Cashaqua	Rhinestreet	Angola	Hanover	Dunkirk	Gardeau	Laona	Wiscoy
BRYOZOA:																									
Fenestella emaciata H.									+																
F. planiramosa H.									+																
Loculipora perforata									+																
Reteporina striata H.									+																
Unitrypa scalaris H.									+																
Polypora multiplex H.									+																
Rhombopora (?) transversa H.									+																
R. polygona H.									+																
R. hexagona H.									+																
R. reticulata H.									+																
R. tortalinea H.									+																
R. lineata H.									+																
R. immersa H.									+																
Acanthoclema scutellatum H.									+																
Streblotrypa hamiltonense									+																
Fistulicella plana									+																
Fistuliporina scrobiculata									+																
F. segregata H.									+																
F. micropora H.									+																
F. minuta H.									+																
F. digitata H.									+																
Paleschara intercella									+																
P. reticulata H.									+																
P. amplectens H.									+																
Lichenalia stellata H.									+																
Stictopora incisurata H.									+	+															
S. sinuosa H.									+																
S. recta H.									+																
S. palmipes H.									+																
S. permarginata H.									+																
Taeniopora exigua Nich.									+																
Acrogenia prolifera H.									+																
Ptilodictya plumea H.									+																
Glauconome carinata									+																
Botryllopora socialis Nich.									+																
Reptaria stolonifera Rolle					+	+			+																
Hederella canadensis Nich.						+			+																
H. filiformis.									+																
H. cirrhosa H.						+																			

	Camillus	Bertie	Cobleskill	Onondaga	Marcellus	Stafford	Cardiff	Skaneatel	Ludlowville	Tichenor	Moscow	Tully	Genesee	Conodont	Styliola	West River	Middlesex	Cashaqua	Rhinestreet	Angola	Hanover	Dunkirk	Gardeau	Laona	Wiscoy
BRACHIOPODA:																									
Lingula leana H.									†																
Lingula della H.									†																
L. spatulata Vanuxem									†				†		†			†	†						
Orbiculoidea media H.									†		†														
O. doria H.											†														
O. lodiensis Van.									†																
Schizobolus truncatus H.											†								†						
S. concentricus						†																			
Crania crenistriata H.						†			†																
C. recta						†																			
Craniella hamiltoniae H.						†			†		†														
Pholidops hamiltoniae H.									†		†														
P. linguloides H.									†	†															
P. oblata H.										†															
Rhipidomella Vanuxemi H.						†			†	†	†														
R. leucosia H.									†	†															
R. penelope H.									†	†															
R. idonea H.										†	†														
R. cyclas H.									†																
Orthothetes arctostriatus H.						†		†	†		†														
O. interstriatus			†																						
O. perversus H.									†																
Stropheodonta demissa Con.									†	†															
S. concava H.									†	†															
S. perplana Conrad						†			†	†	†														
S. inequistriata Conrad						†			†	†	†														
S. nacrea H.									†	†															
S. junia H.									†																
S. plicata H.									†																
Chonetes mucronatus H.					†	†	†	†	†	†	†														
C. vicinus Castelnau								†	†	†	†														
C. setigerus H.							†	†	†																
C. scitulus H.					†	†		†	†	†	†														
C. lepidus H.						†	†	†	†		†				†			†							
C. coronatus Conrad									†	†															
Productella navicella H.										†															
P. spinulicosta H.						†	†	†	†	†	†														
Strophalosia truncata H.					†	†	†	†	†																
Spirifer mucronatus Con.							†	†	†		†														
S. tullius H.											†				†										
S. sculptilis H.										†															
S. consobrinus D'Orbigny										†	†														
S. granulosus Conrad								†	†	†															
S. audaculus Conrad									†	†	†														
S. eriensis			†																						
S. angustus H.									†																
S. macronatus H.									†	†															
S. asper H.									†																
S. fimbriatus Conrad						†			†	†															
S. subumbonus H.						†			†		†														
Ambocoelia umbonata Conrad							†	†	†	†	†														
A. nana Grabau					†	†		†	†																
A. praeumbona H.					†						†														
A. spinosa Clarke						†			†		†														
Cyrtina hamiltoniensis H.									†		†														
Parazyga hirsuta H.									†																
Trematospira gibbosa						†			†																
Nucleospira concinna H.						†			†	†	†														
Athyris spiriferoides									†	†	†														
Meristella haskinsi H.										†															
M. rostrata H.										†															
M. barrisi H.						†			†																
Atrypa reticularis Linnaeus							†		†		†														
A. spinosa H.											†														
Vitulina pustulosa H.										†															
Camarotoechia horsfordi H.						†			†	†	†														
C. pauciplicata						†																			
Camarotoechia sappho H.						†			†	†															
C. prolifica						†																			
C. dotis H.								?	†	†															
C. congregata Conrad									†																
Leiorhynchus multicostus H.									†		†														
L. quadricostatum Van.											?														
L. limitare Van.					†	†	†	†																	
L. dubium Hall									†																
Centronella impressa H.										†															
Trigeria lepida H.										†															
Cryptonella planirostris H.						†				†															
Cryptonella rectirostris H.						†			†																
Dielasma romingeri H									†																
Tropidoleptus carinatus Con.					†	†			†	†															
Meristella meta Hall						†																			
M. barrisi H.						†	†																		
Whitfieldella sulcata			†																						
W. nucleolata			†																						
W. cf. laevis			†																						
Rhynconella (species)			†																						

	Camillus	Bertie	Cobleskill	Onondaga	Marcellus	Stafford	Cardiff	Skaneateles	Ludlowville	Tichenor	Moscow	Tully	Genesee	Conodont	Styliola	West River	Middlesex	Cashaqua	Rhinestreet	Angola	Hanover	Dunkirk	Gardeau	Laona	Wiscoy
PELECYPODA:																									
Aviculopecten princeps Con.									†	†															
A. exacutus H.					†				†																
A. insignis H.									?																
Lyriopecten orbiculatus H.									†	†															
Pterinopecten conspectus H.									†		†														
P. exfoliatus						†																			
P. hermes H.									†																
Pterinea flabella Conrad									†																
Actinopteria decussata H.									†	†															
A muricata						†																			
A. boydi H.									†																
Leiopteria rafinesquii H.									†																
L. conradi H.									†																
Plethomytilus oviformis Con.										†															
Gosselettia retusa H.									†																
Modiomorpha concentrica Con.									†	†															
M. sub-alata Conrad					†				†																
M. alata Conrad									†																
Goniophora modiomorphoides										†															
Cypricardella bellistriata Con.								†	†	†															
Nucula corbuliformis H.									†																
Nuculites oblongatus Con.								†	†																
N. nyssa H.					†			†																	
N. triqueter Con.					†		†	†																	
Schizodus appressus Con.									†																
Palaeoneilo constricta Con.									†														†		
P. tenuistriata H.								†	†		†														
P. fecunda H.									†		†														
P. muta H.								†	†		†														
P. emarginata Con.									†																
Macrodon hamiltoniae H.									†																
Grammysia arcuata Con.									?																
Sphenotus truncatus Con.									†																
Conocardium normale H.										†															
C. eboraceum H.										?															
C. crassifrons Con.									?																
Lunulicardium ornatum H.													?												
L. curtum H.					†		?		?																
Paracyclas lirata Con.							†																		
Tellinopsis sub-emarginata Con.								†																	
Pholadella radiata Con.									†																
Orthonota (?) parvula H.					†				†																
Cardiola retrostriata von Buch								†										†							
Cypricardinia indenta						†			†		†														
Elymella nuculoides H.									?																
Modiella pygmaea Con.								†	†																
Panenka linklaeni					†	†																			
P. mollis						†																			
Productella dumosa H.						†																			
Lunulicardium libum																								?	
L. accola																					†				
L. eriense																								†	
L. furcatum																								?	
L. pilosum																		†							
L. bickense																				†			?		
L. beushauseni																							†	?	
L. suppar																							†	?	
L. sp. nov.																							†		
Pterochaenia fragilis H.					†	†	†	†	†				†		†			†	†						
P. elmensis																		?	†						
Posidonia attica																			?	?					
P. mesacostalis																							?	?	
P. venusta Münster																							†		
Kochia ungula																							†		
Loxopteria dispar Sandberger																							†		
L. laeris Frech																							†		
L. vasta																							†		
L. corrugata																							†		
Ontaria concentrica																							†		
Ontaria pontiaca																					†				
Euthedesma subtextile Hall																							†		
Elasmatium gowandense																							†		
Buchiola scabrosa																				†	?				
B. conversa																				†					
B. angolensis																				†					
B. lupina																				†					
B. prümiensis steininger																				†					
Praecardium vetustum Hall																							†		
P. melletes																								†	
P. duplicatum																								?	
P. multicostatum																							†		
Conocardium gowandense																							†		
Palaeoneilo petila																				†					
P. brevicula																							†		
P. linguata																							?	?	
Leptodesma marcellense H.					†																				

	Camillus	Bertie	Cobleskill	Onondaga	Marcellus	Stafford	Cardiff	Skaneateles	Ludlowville	Tichenor	Moscow	Tully	Genesee	Conodont	Styliola	West River	Middlesex	Cashaqua	Rhinestreet	Angola	Hanover	Dunkirk	Gardeau	Laona	Wiscoy
GASTROPODA:																									
Platyceras erectum H.									†																
P. carinatum H.									†	†															
P. thetis H.									†																
P. bucculentum H.										†															
P. symmetricum H.									†																
P. attenuatum H.						†			†	†															
Platyostoma lineata Conrad									†	†	†														
Loxonema hamiltoniae H.								†																	
L. delphicola H.								†																	
L. (?) coapta H.										†															
Loxonoma breviculum H.									†																
Eccyliomphalus laxus H.							†	†		†															
Straparollus rudis H.										†															
Pleurotomaria lucina H.						†			†	†															
P. itys H.						†			†																
P. capillaria Conrad						†		†																	
P. planidorsalis H.									†																
P. rugulata H.					†				†																
Bellerophon patulus H.									†																
B. leda H.								†	†																
Pleurotomaria itylus																							†		
Phragmostoma chautauquae																					†		†	?	
Loxonema danai																							†	?	
Palaetrochus praecursor Clarke																					†				
Callonema filosum																							?		
Diaphorostoma rotundatum																				†					
D. pugnus																			?	?					
Onychochilus (?) nitidulus C.					†																				
Loxonema (species)			†																						
Pleurotomaria (species)			†																						
Hercynella buffaloensis		†																							
H. patelliformis		†																							

	Camillus	Bertie	Cobleskill	Onondaga	Marcellus	Stafford	Cardiff	Skaneateles	Ludlowville	Tichenor	Moscow	Tully	Genesee	Conodont	Styliola	West River	Middlesex	Cashaqua	Rhinestreet	Angola	Hanover	Dunkirk	Gardeau	Laona	Wiscoy
PTEROPODA:																									
Styliolina fissurella H.					†	†	†	†		†			†	†											
S. spica H.								†																	
Tentaculites bellulus H.								†		†															
T. gracilistriatus H.					†	†	†	†		†															
Coleolus tenuicinctum H.					†			†																	
C. gracilis H.								†																	
Conularia undulata Conrad								†																	
Hyolithus neapolis Clarke																							?		
CEPHALOPODA:																									
Nautiloidea:																									
Orthoceras eriense H.					†			†																	
O. subulatum H.					†		†	†	†	†															
O. exile H.					†	†		†																	
O. marcellense H.					†																				
O. telamon H.									†																
O. aegea					†	†																			
O. aulax H.								†																	
O. fenestrulatum					†																				
O. nuntium H.								†																	
O. emaceratum H.								†																	
O. constrictum Vanuxem								†																	
Gomphoceras manes H.												†													
G. lunatum H.								†																	
Nautilis magister H.								†																	
N. marcellensis Van.						†																			
AMMONOIDEA:																									
Bactrites gracilior Clarke														†?											
B. aciculum H.												†					†								
Goniatites uniangularis Conrad								†																	
G. bicostatus H.																		†?	†?						
G. lutheri Clarke																	†								
G. complanatus Hall																	†?	†?							
G. intumescens Beyrich																	†								
G. rhynchostoma Clarke																		†							
G. sororium Clarke																		†							
G. holzapfeli Clarke																	†?								
Gephyroceras domanicense																		†							
Goniatites vanuxemi					†																	?			
Trochoceras gebhardi		†																							

	Camillus	Bertie	Cobleskill	Onondaga	Marcellus	Stafford	Cardiff	Skaneateles	Ludlowville	Tichenor	Moscow	Tully	Genesee	Conodont	Styliola	West River	Middlesex	Cashaqua	Rhinestreet	Angola	Hanover	Dunkirk	Gardeau	Laona	Wiscoy
CRUSTACEA:																									
Primitia seminulum Jones										†															
Primitopsis punctulifera H.					†	†			†																
Entomis rhomboidea Jones									?																
Strepula sigmoidalis Jones									†																
S. plantaris Jones									†																
Beyrichia hamiltoniensis Jones									†																
B. tricollina Ulrich									†																
Isochilina (?) fabacea Jones					†				†																
Leperditia hudsonica H.										?															
L. scalaris		†																							
Aechimina marginata Ulrich									†																
Ctenobolbina minima Ulrich									†																
Moorea bicornuta Ulrich									†																
Bairdia leguminoides Ulrich									†																
TRILOBITAE:																									
Homalonotus dekayi Green									†																
Phacops rana Green					†	†	†	†	†	†	†														
Dalmanites (Cryphaeus) boothi					†	†			†	†	†														
Proteus macrocephalus H.										†															
P. rowi Green		†							†																
P. curvimarginatus H.		†							†																
Phaethonides gemmaeus H.									†																
Cyphaspis ornata H.		†							†																
C. craspedota						†																			
EURYPTERIDA:																									
Eurypterus lacustris H.		†																							
E. remipes H.		†																							
E. pustulosus H.		†																							
E. lacustris pachychirus H.		†																							
E. dekayi H.		†																							
Dolichopterus macrochirus H.		†																							
Eusarcus grandis Grote		†																							
E. scorpionis Grote																									
Pterygotus cobbi H.																									
P. buffaloensis Pohlman																									
PHYLLOCARIDA:																									
Ceratiocaris acuminata H.		†																							

Description of Some New Siluric Gastropods.

BY MARJORIE O'CONNELL, A. M.

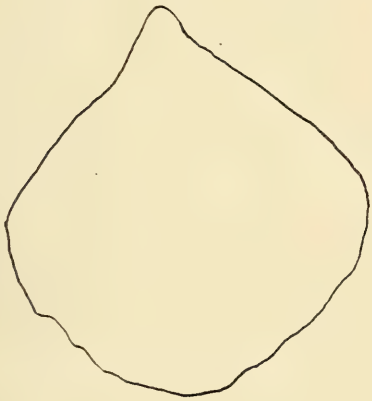
About a year and a half ago while examining the entire collection of fossils from the Bertie Waterlime exhibited in the Museum of the Buffalo Society of Natural Sciences, my attention was called by Professor A. W. Grabau to a number of specimens which appeared to belong to the gastropod genus Hercynella. With the view of making a more careful determination of these specimens I have, through the kindness of Mr. Henry R. Howland, Superintendent of the Buffalo Society, had the specimens sent to me for closer study and comparison with some of the type material of the Bohemian forms of Hercynella presented to the Palæontological Museum of Columbia University by Professor J. Perner of Prague.

Since Hercynella is practically unknown from this country, a general description of the genus and its distribution will be given before considering the new species. The generic name Hercynella was proposed by Emanuel Kayser in 1878 for certain pulmonate gastropods, ranging from Middle Siluric (E 2) through Middle Devonic (G 3) in age. Barrande had discovered this fauna in Bohemia, and, identifying his forms with the living genus Pilidium Forbes, created the genus Pilidion, of which he recognized two species *P. bohemicum*, a high cone and *P. nobile*, a flat one. Barrande used this name Pilidion in his manuscript as early as 1865 and it appeared in print in 1868 in the *Thesaurus Siluricus* of Bigsby to which author Barrande had himself communicated the name. Furthermore, the name Pilidion appeared in Barrande's own handwriting on the labels sent with duplicate material to various museums, so that the authenticity of the name cannot be denied. That it has been replaced in the literature by the name Hercynella which was proposed some thirteen years later for the same species, is due to the fact that Kayser considered that Barrande had been mistaken in identifying the Bohemian gastropods, which are asymmetric, with the recent Pilidium which is symmetric. Perner who has continued

Barrande's work in Bohemia and has decribed the specimens subsequently found, accepts the new name proposed by Kayser, not, however, for any of the reasons given by the latter author, but on philological grounds, for if the name Pilidion were latinized it would become the homonym of Pilidium Forbes. For this reason only does Perner replace *Pilidion* Barrande by *Hercynella* Kayser. Since the species *bohemica* was the type for Barrande's genus, it remains the type of Hercynella.

So far as known, the geologic range of Hercynella is small. Furthermore, it has been recorded from only three localities; the first is Bohemia, from which fifteen species have been described, some by Barrande, the rest by Perner; the second is Harz mountains, where Kayser found two species; and the third is in America in the Monroe formation of Michigan from which Grabau described one species. *Hercynella canadensis* Grabau is represented by a single incomplete specimen, but much interest attaches to it, since it is the only member of the genus which has heretofore been described from this country, and the very fact of its occurrence has probably been noted by few. It is, then, of considerable interest to find in a still earlier horizon in this country several specimens of this rare genus Hercynella, making a new locality and horizon in America and the fourth locality in the world.

The typical Hercynella is a patelliform, non-spiral gastropod, having the apex of the shell asymmetrically situated, and varying in form from a low cone to a flat inverted basin with very gently sloping sides. The characteristic of especial importance is a radial depression passing from the sub-central apex to the border, and bounded upon one side by a pronounced angulation in some cases, but in others merging imperceptibly into the general curvature of the shell. In most descriptions the angulation is the feature which is emphasized, whereas in reality it is the depression or sinus which is marked, since the shell growth in the majority of cases follows a definite curvature and then makes a sudden drop, forming the sinus, beyond which the shell continues at a lower curvature. For this reason it seems advisable to lay stress upon the sinus, not the ridge, since the latter is related to a true fold or ridge in the same way that a monoclinal flexure is related to an anticline. It would be only in the case of a ridge rising above the general curvature of the shell and not bounded on either side by a sinus, as in H. rigescens from the middle Devonic G, of Bohemia or in the case of two radial depressions with fold between, of which however, there is no known instance, that we could truly speak of a radial fold or crest. In none of the material from Bohemia which I have examined, and in only a few of the illustrations of Hercynella have I seen a true ridge, but in most cases there was only a monoclinal flexure, such as is well illustrated in H. radians Barr. sp. from F, of Bohemia (fig. 2). In the most high coned forms the sinus is, as a rule the deepest, while in those which have a lower cone, approaching a very flat patelloid condition, the sinus is shallower and may, indeed, be hardly noticeable. With the variation in depth of the sinus there is an accompanying variation in the marginal outline of the shell, forms with a pronounced sinus having a sharp re-entrant, while flatter ones show a shallow re-entrant approaching an entirely convex curvature for the whole periphery. The surface of the shell bears concentric lines of growth and frequently ribs, which in some cases are quite pronounced. Some species also show radial striæ.



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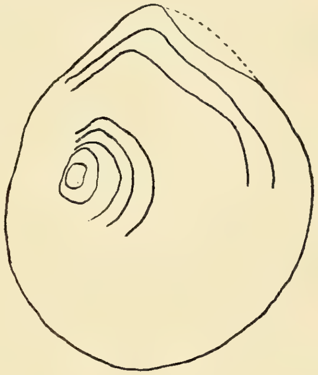

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FIG. 1. Outline of *Hercynella regescens* Barr. sp. from G, of Bohemia, x 4/5.

FIG. 2. Outline of *Hercynella radians* Barr. sp. from F, of Bohemia, showing the young stages as indicated by the growth lines, x 4/5.

The specimens from the Bertie Waterlime clearly represent two species, and it is singular to note that, just as Barrande in describing the first Hercynellas from Bohemia, found a high coned form which he called *Pilidion bohemicum* and a low coned one which he called *P. nobile*, and just as Kayser describing the fauna from the Harz found a high spired Hercynella corresponding to the former, which he called *H. hauchecorni* and a low spired one corresponding to the latter, which he called *H. beyrichi*, so in the Bertie fauna there is one species with a high apex and one which is very flat.

The Bertie material is very unsatisfactory, for while the form of the shell is well preserved, the details of surface markings are indistinct and a precise description is therefore impossible. The shell was apparently very thin and may have been only slightly impregnated with lime or even entirely corneous, for which reason it is to be expected that the shell would be more or less macerated. Some portions would remain in place, but others would stick to the mud in which the shell was buried, and, fossilized, would appear now in the mold. Thus little patches of shell are visible on both mold and relief, and since the shell is so thin that it leaves little more than a black film of organic matter on the rock, the difficulties in making observations on growth lines, striæ and so forth are obvious. There is no way of orienting the shell, since the internal features are not visible, and since in the better preserved material of Bohemia it has been observed that the position of the sinus is variable. We may, therefore, for convenience sake speak of the right and left, and posterior and anterior portions of the shell with reference to a line of symmetry drawn through the sinus, which is placed anteriorly and the figures throughout the paper will be oriented in this way and referred to accordingly.

Hercynella buffaloensis sp. nov.

Description:—Shell patelliform, sub-circular, non-spiral. The beak is destroyed, but its position would be asymmetric, the shell showing an abrupt drop on the right side (see pl. I fig. 1) and a gentle slope on the left. Growth lines are clearly visible on most of the shell, being particularly strong at the margin. The growth lines show strong incurving with the formation of a peripheral sinus. A few fine striæ are faintly indicated to the left of this sinus. Length of shell: 25 mm.; width: 26 mm.; height from beak to base: 5 mm. in specimen (restored height about 7 mm.)

This is the high coned form corresponding to Barrande's *Hercynella bohemica*, though differing from it considerably. It is much smaller than the majority of the Bohemian species, but it conforms to the law observed among them, that, in the same horizon the high coned forms have a more pronounced sinus than the low coned ones, and this will be seen to be the case from a comparison of the figures of *H. buffaloensis* and *H. patelliformis*.

The asymmetry of the shell is more pronounced than in *H. patelliformis*, the apex being situated about 4 mm. to the right of a median line. This excentric position of the apex has not, however, caused any elongation of the shell, for this has an almost perfectly circular outline of base. The relative positions of the apex and sinus are very different in the two species: in *H. buffaloensis* the sinus is not on the line passing through the greatest and least slope, but is ninety degrees removed at the shell margin, while in *H. patelliformis* the sinus coincides with the axis of greatest elongation.

To the left of the radial sinus are a few striæ so faint that they are barely discernible under a high power lens, but of their presence there can be no doubt, for while continuous lines from beak to base cannot be traced, the points of intersection of the striæ with the lines of growth can be seen, giving the same type of ornamentation figured by Barrande for *Hercynella nobilis Barr.*, though not so well defined.

Horizon and Locality:—In the Bertie Waterlime of North Buffalo. Six specimens. Types in the Museum of the Buffalo Society of Natural Sciences.

Hercynella patelliformis sp. nov.

Description:—Shell patelliform, elliptical, non-spiral. The beak is destroyed, but its position as shown by the curvature is asymmetric. Lines of growth show on peripheral portions of the shell. In places there are faint concentric undulations, but they cannot be traced completely around the shell. There are no radiating striæ. There is no sharp sinus or elevated fold or ridge, but the growth lines bend in on the posterior margin indicating the presence of a slight sinus. Length of shell: 61.7 mm.; width: 49.1 mm.; height from beak to base: 11.9 mm.

There are but two specimens from which we can describe this species, one of these being the exterior of the shell and the other the mold of the same. Little patches of shell are visible on both specimens, the mold showing a very thin film of organic matter, just sufficient to make the rock black. The most striking feature of the shell, and the one which, together with the asymmetry, forms the chief diagnostic characteristic, is the marked incurving of the growth lines in the posterior portion of the shell, along the steeper slope of the long axis. (Pl. I, fig. 4.) For a distance of 6 mm. from the periphery of the shell, the growth lines curve in from both sides, showing that, at the edge of the shell which is invisible, there must be quite a sinus as indicated in fig. 3. Such a sinus represents a simple and primitive condition of the much more highly specialized one which is seen in some of the Bohemian forms. It is evident that the ancestral Hercynellas must have had only the slightest radial depression, or perhaps none at all, and this shallow depression would be accompanied by a correspondingly shallow re-entrant in the periphery. If it be assumed, that, as was most likely the case, this radial depression was produced by the appearance of the siphon, then we can easily think of a time when there was no siphon and when the curvature of the shell was regular and without interruption. Moreover, the gradual development of

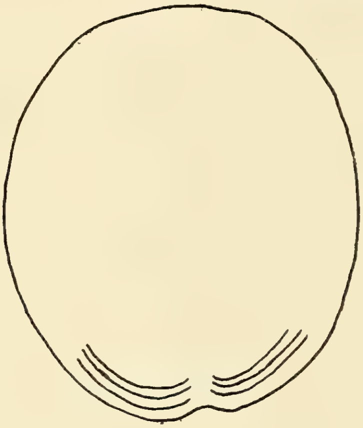

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FIG. 3. Restored peripheral outline of *Hercynella patelliformis* sp. nov. as suggested by the growth lines in pl. I, fig. 4. x 4/5.

the siphon at first may have had no expression in the shell. As, however, the siphon became more prominent, there would be a gradual change in the mature shell at the periphery. This change would at first be slight, would become more pronounced with the increased size of the siphon.

The shallow sinus which is visible only in the adult of *Hercynella patelliformis* is present even in the young of the Bohemian forms, though in the very earliest part of the shells of the latter the growth lines show a regular curvature with no sinus. (Fig. 2.) It would seem, then, as though this species from the Bertie horizon represented the ancestral condition of the Hercynellas before they had acquired the pronounced radial depression. I do not mean that the forms which lived in the Bertie time were the direct ancestors of the forms living in Bohemia in the upper Siluric and lower Devonic time, but rather that the ancestors of the Bohemian forms which, to be sure, have not yet been found, must have been quite similar to those which are found in the Bertie, and that if Hercynellas were found in this country in a higher horizon, they would probably resemble the Bohemian forms to the extent of having such a pronounced radial depression with consequent marginal sinus. In fact, the one other Hercynella from this country, *H. canadensis* Grabau does show just the features which would be expected. (Grabau and Sherzer, Monroe formation of southern Michigan, pl. xxv, figs. 5, 6.)

Along the gentle slope of the longer axis may be seen a number of slight concentric undulations, five or six being clearly traceable half way around the shell. These are evenly spaced, four occuring within a distance of 5 mm. They apper most like the concentric undulations so marked in *H. bohemica*, but are much fainter and more difficult to trace. Of radial striæ there is not the slightest indication.

Horizon and Locality:—Associated with the preceding in the Bertie Waterlime of North Buffalo. Two specimens. Types in the collection of the Buffalo Society of Natural Sciences.

Relation of the Hercynellas from the Bertie to those of other Horizons.

The species which have just been described are placed under the genus Hercynella because they more closely resemble the forms included by Barrande under that genus, than they do any other gastropods that have been described. In their lack of ornamentation and their shallow sinus they seem to fulfill the theoretic requirements for the hercynelloid ancestor. There is some tangible proof that this is the close correspondence between the adult shell form and outline of the species from the Bertie and those of the young stages of the species from Bohemia. It is evident that the forms in Bohemia were much more specialized than those from the Waterlime, for even those from the lowest European horizon, E 2, which corresponds to the Monroan in America, already showed a pronounced radial sinus and strong radiating striæ. These two new species are so very different from Barrande's type (*H. bohemican*) and so much more primitive, that it would almost seem advisable to put them in a new genus, except for the fact that the material from which they are described is too poor to allow a complete and exact enough description to be made for the founding of a new genus. In case more and better material be discovered in the future, there might then seem to be sufficient grounds for separating these species from Hercynella, in which case I propose the generic name Hercynellina.

Habitat of Hercynella.

The horizon in Bohemia in which the largest number of Hercynellas has been found is F, or upper Monroan. Here they are associated with vast numbers of graptolites and also with sponges, trilobites and tentaculites. The fauna is undoubtedly marine, and since it is well preserved and the Hercynellas also are numerous and in good condition, there is no reason for questioning the marine habitat of the species in Bohemia. Furthermore, the shells are comparatively thick, showing no lack of carbonate of lime for impregnation. The one specimen from the Monroe limestone of Michigan likewise has good marine associates, though its macerated condition and the fact that no other specimens have been found would leave it an open question whether it was a true marine form or merely one swept out to sea by land waters. The Hercynellas which have been found in the Bertie waterlime seem to indicate conditions other than marine, for their shells are exceedingly thin, as though available lime were not abundant in the water in which they lived, and, moreover, their faunal associates are not typical marine forms, there being only eurypterids, ceratiocarids and the plant *Buthrotrepis lesquereuxi*, together with a few water-worn specimens of Orthoceras. The writer has elsewhere * discussed at length the significance of this unique fauna and the bionomic conditions which it indicates. The very thin shell of these pulmonate gastropods may be taken as a slight bit of additional evidence to that given in the paper above referred to in support of the view that the Bertie waterlime was deposited not in marine water, but in brackish of fresh water, and that the Hercynellas as well as eurypterids were carried into the Bertie muds by the rivers. If, on the other hand Hercynella is to be regarded as a marine genus, then we have here another case of intermingling of marine and fluviatile species in the region of deposition at their junction.

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* Bulletin of the Geological Society of America, Vol. XXIV, pp. 499-515. 1913.

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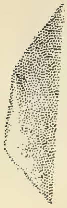
Palæontological Laboratory,
Columbia University.



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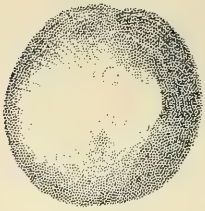

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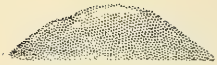

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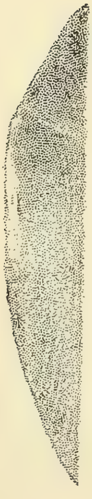

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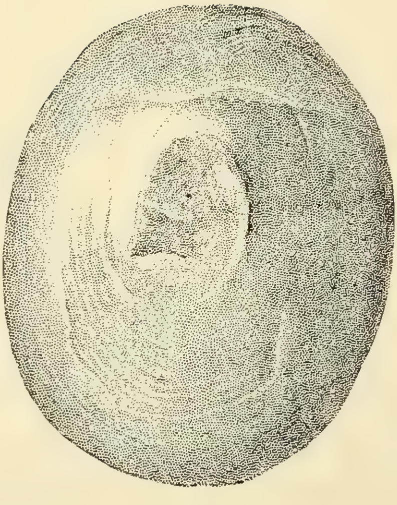

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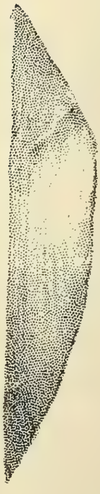

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Explanation of Plate.

The specimens are in the collection of the Museum of the Buffalo Society of Natural Sciences. They all come from the Bertie waterlime (Monroan) of North Buffalo. The illustrations are natural size.

Fig. 1. *Hercynella buffaloensis*, sp. nov. Top view of type specimen, showing assymetric position of apex.

Fig. 2. Front view of same.

Fig. 3. Side view of same.

Fig. 4. *Hercynella patelliformis*, sp. nov. Top view of type specimen.

Fig. 5. View of right side showing gentle slope.

Fig. 6. View of left side showing steep slope.

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of the

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1915

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1915

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of the Dipterous Genus Diaphorus.
By
M. C. VAN DUZEE.

* * *

A Jivaro War Trophy.

A Mundrucu Mummied Head Trophy.

BULLETIN

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VOLUME XI. No. 2

INTRODUCTION.

The exhibit recently installed in the Museum of the Buffalo Society of Natural Sciences to show the early development of the Art of Writing includes twenty-one inscribed clay tablets from lower Mesopotamia. Of these five have come from Dréhem, a ruin-mound about three miles south of Nippur where were stock pens of the cattle market which supplied animals for sacrifice at the temples of Nippur, especially the great temple of Enlil and his consort Ninlil, in the latter part of the prosperous Dynasty of Ur. Eleven are from Jokha, the modern name of the ancient city of Umma, while four are from Senkereh, which was the Biblical city Ellaser of Genesis 14.1, and one is a votive tablet from Warka, that being the modern name of the Biblical city of Erech (Uruk) of Genesis 10.10.

These have been deemed of such interest that their translation seemed desirable and for that purpose they were placed in the hands of Dr. Mary Inda Hussey, Associate Professor of Biblical Literature at Mount Holyoke College. Their translation follows with such an account of them from her pen as cannot fail to interest its readers.

The dynasty of Ur founded about 2300 B. C. by Ur-Engur, represents Sumerian supremacy, the Semitic dynasty of Akkad having been then overthrown.

All of southern Babylonia—Uruk (Erech), Larsa (Ellaser, now Senkereh), Lagash (now Telloh) and Nippur (Niffer)—was brought under its sway; then Elam was conquered. Southern Babylonia was divided, it will be seen, into city kingdoms, one of which held the hegemony over the others. Edward Meyer (Geschichte des Altertums, 2nd Edition, 1909), gives the dynasty of Ur as follows:

Ur-Engur	2304-2287	B. C.
Dungi	2286-2229	"
Bur-Sin	2228-2220	"
Gimil-Sin	2219-2213	"
Ibi-Sin	2212-2188	"

The best known kings of Uruk (the Biblical Erech) are Singashid and Sin-gamil, who seem to have ruled about 2150-2110 B. C.

With these tablets is shown an interesting collection of seal cylinders from Babylonia, including archaic examples in shell and marble as well as those cut in hematite, steatite, agate, etc., of later date.

The exhibit referred to includes examples of early Egyptian writing on stone, on papyrus, on linen and on terra cotta, showing the early hieroglyphs, the conventionalized abridged form of these known as the Hieratic writing, employed by the priests in their records, and the later so-called Demotic form, employed in common use, adapted to the needs of everyday life.

HENRY R. HOWLAND,

Superintendent.

Babylonian Tablets

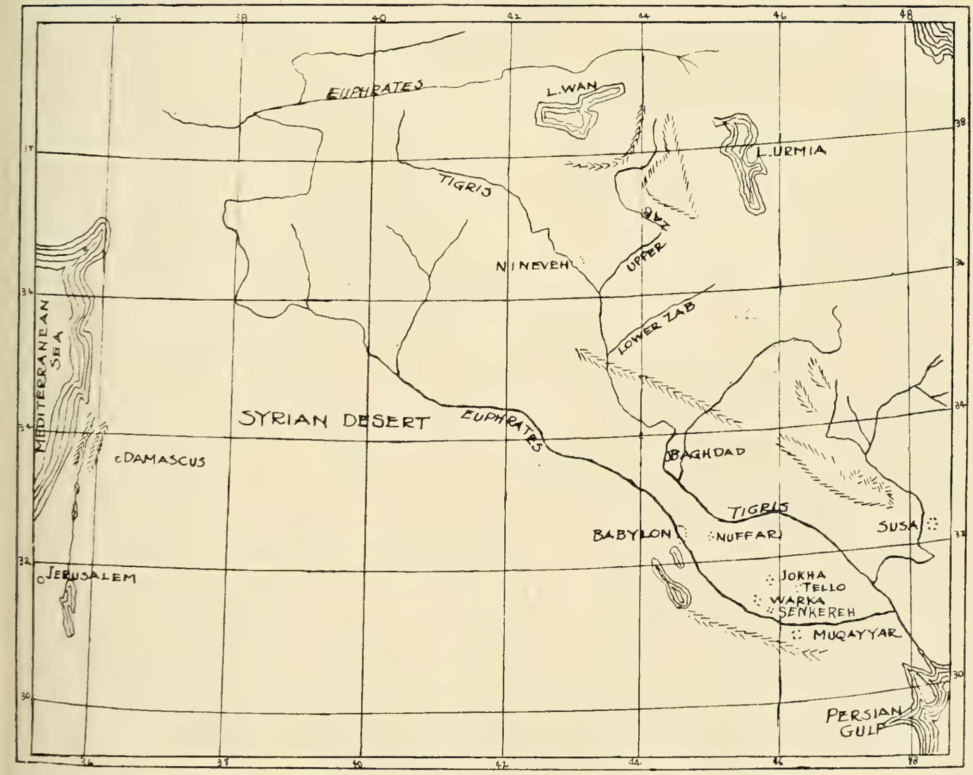
in the Museum of

The Buffalo Society of Natural Sciences

by

MARY INDA HUSSEY, PH. D.

The twenty-one tablets, the cuneiform text of which is published in the following pages, were acquired by the Buffalo Society of Natural Sciences in 1913. Their purchase was made possible by the extensive clandestine excavations that have been carried on during recent years in Babylonia by the native Arabs. These Arabs found out that Europeans and Americans were willing to exchange money for the pieces of clay that were to be found by


EUPHRATES
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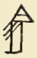
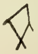
DAMASCUS
BAGHDAD
TIGRIS
BABYLON
NUFFAR
SUSA
JERUSALEM
JOKHA
TELLO
WARKA
SENKEREH
MUQAYYAR
PERSIAN GULF

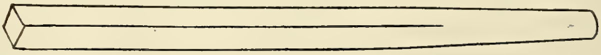
MAP OF WESTERN ASIA

digging in the soil of what appears to be natural hills, between the lower course of the Tigris and Euphrates rivers. But the Tigris-Euphrates valley is a fertile alluvial plain like the Nile valley, and these gently sloping hills are in reality the ruins of cities that were the marts of the world four thousand years ago.

In this valley there was neither wood nor stone, except what was brought there from distant mountains. Driven by this lack of a natural building material, necessity forced them to find it in the soil. Burnt bricks were used for outer walls, for drainage and cisterns, but the thick inner walls were made of sun-dried brick. Hence it came about that after a city had been destroyed by an enemy, the rain, or the overflowing of a canal or river, soon converted the sun-dried bricks into the original clay from which they had been made; the process of erosion softened the harsh lines into a gently sloping mound or hill, the wind bore seeds thither that soon covered the whole mass with verdure, and the once flourishing city was rendered indistinguishable from a low hill. So it was that Xenophon and his brave band of ten thousand men passed by the ruins of Nineveh, little dreaming that two centuries before his day it had been one of the foremost cities of the world, and three-quarters of a century earlier the capital of a great world-empire.

Necessity forced the inhabitants of this valley to use the same material for writing as for building. The fact that their writing is cuneiform, i. e., wedge-form, is an accident due to the character of this material. The earliest writing in Babylonia appears to have been on stone and consists of pictographs drawn with straight lines. Thus,

 is the picture of a human head; represents a foot;  is a fish; represents water. When these same characters were drawn on soft clay with a reed-wood stylus (see the models made by Prof. A. T. Clay), the stylus made a triangular de-



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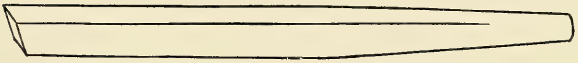


BEVELED END STYLUS

pression where it was impinged upon the clay. The characters soon became so conventionalized that the original pictograph was lost and can be discerned only after arduous study.

The language which was written in these cuneiform characters is known as Sumerian and the people as Sumerians. Whence these Sumerians came into the Tigris-Euphrates valley, whether by land or sea (Persian Gulf), is entirely unknown. No attempt to prove kinship with any other known people or language has been successful. The earliest remains in Babylonia probably do not antedate 3000 B. C., and are characterized by a comparatively advanced state of culture. The earliest documents are written in Sumerian, which continued to be the language of religion, legal procedure, and commerce for about a thousand years. Then business documents began to be written in a Semitic tongue with these same cuneiform characters, just as we write English with Latin letters. It is due to this borrowing on the part of the Semites from the Sumerians of their method of writing, that Semitic Babylonian is also written in cuneiform and is the only one of the Semitic group of languages that is written without an alphabet. The amalgamation of these two races has left traces of itself in the proper names found in these documents. At first all names of persons are Sumerian, but gradually as the Semitic race gained the preponderance and finally the supremacy over the Sumerian population whose higher culture they adopted, Semitic names appear, then finally entirely displace Sumerian names. It is only when Semitic names are written in syllables that they are to be distinguished with certainty from Sumerian names. Here are a few examples of Semitic names from Tablets Nos. 18 and 20: En-zu-i-ki-sha-am, "the god Enzu has presented"; En-zu-im-gu-ra-an-ni, "the god Enzu was favorable"; En-zu-ish-me-a-ni, "the god Enzu has heard me"; A-bu-wa-qar, "the father is dear."

Clay that was to be used for writing material was well washed to free it from sand. It had such great adhesive power that tablets that were merely sun-dried and have remained buried in the earth for four thousand years are often still in a good state of preservation. Ten of the tablets here published were unbaked. When tablets become exposed to air as damp as our atmosphere often is, their disintegration begins. While lying buried in the ground for these thousands of years they absorbed salt from the soil. Since salt crystalizes in moisture, small salt crystals form which pry off layer after layer of the tablet. One damp morning Tablet No. 18 of this collection was found with the entire surface of the tablet loosened, and underneath a thin layer could be seen by the naked eye a white frosting of salt crystals. Hence the necessity of baking the tablets thoroughly, and then allowing them to stand in water until all the salt has been dissolved out of them.

Contracts, acknowledgments of a loan, letters, and various other records were protected by clay envelopes, upon which practically the same record was written as upon the tablet itself. This enabled the parties to the contract to consult the terms of the contract, but prevented it from being altered, for the envelope and the inner tablet must agree and any alteration would be detected. No. 15 is such a tablet. The envelope or case had become cracked and it was opened for the first time in October, 1913, some 4153 years after it had been written. No. 14 is a case tablet, as these tablets with envelopes are called, which has never been opened.

These documents were furthermore protected and authenticated by one or more impressions of the notary's seal, or sometimes the seal of the debtor, which was equivalent to his signature. These seal cylinders used for the seal impressions were made of semi-precious stone, such as agate, lapis lazuli, jasper, shell, onyx, and one was probably owned by every man of standing in the community, for writing was done by the scribe. At the period from which these tablets came, a seal contained not only the name of its owner, his profession, and the name of his father, but also represented some religious scene. The scene on No. 6 is that of a god wearing a turban, seated on a throne and holding a goblet in his extended hand. A goddess clothed in a long garment and a cap with two horns is leading a worshipper wearing a fringed garment. Between the seated god and the approaching goddess is a four-legged little animal (a monkey?) that is trying to get upon the god's lap. The inscription on the seal reads: (to) Eanisha, priestess, beloved of the king, Nadi, son of [. . . .], thy servant. On No. 8 there are twenty-three impressions of the notary's seal. Some of the wedges have been obliterated by the pressure of the seal upon the soft clay, making it very difficult to read. The seal on No. 16 is that of a royal scribe. It reads: (To) Dungi, the mighty hero, king of Ur, king of the four quarters, Ludugga, the scribe, son of Nigingardugga, thy servant. Before the turbaned god seated on the throne there stands a worshipper for whom the goddess is making intercession.

Eighteen of the tablets here published come from the time of the dynasty of Ur (2300-2200 B. C.), most of them being dated in the reign of three of the five kings of that dynasty, namely, Dungi, Bur-Sin and Gimil-Sin. The form of the writing of two of the undated tablets (Nos. 18 and 20) is that of the first dynasty of Babylon (2060-1761 B. C.). No. 21 is from the reign of Sin-gashid, king of Uruk (the Biblical Erech), who was probably a contemporary of one of the earlier kings of the first dynasty of Babylon. It records his building of a palace. The religious character of the time is illustrated by one of the royal titles, "he who cares for Eanna," the temple of the goddess Ishtar in Uruk.

At the time of the dynasty of Ur it was customary to name the year after some event of public interest. From the reign of Dungi we have the following years: No. 8, "The year after Simuru was devastated for the third time"; No. 21, "The year when (the temple named) Ebashaishdagan was built"; No. 22, "The year when Shashru was devastated." Nos. 3, 7, and 11 are from the seventh and eighth years of the reign of Bur-Sin, which years were named, "The year when Huhunuri was devastated," "The year when the high priest of Eridu was installed." No. 13 is dated in "The year after the devastation of Simanu," and No. 5 in "The year when Gimil-Sin the king devastated the land of Zabshali." These are from the fourth and seventh years, respectively of the reign of Gimil-Sin. It will readily be seen what a valuable source of information for the history of the period such date-formulas are in the record they give of foreign campaigns and internal improvements. From the dates mentioned above one may see the expansion of the empire under King Dungi to the districts east of the Tigris river in his conquest of

Simuru, and into Elam—that great centre of civilization which lay upon the eastern frontier with its capital at Susa—in his conquest of Shashru. This policy of expansion eastward was maintained by his son Bur-Sin in his expedition against Huhunuri and by his grandson Gimil-Sin who conquered Simanu and Zabshali.

No. 5 belongs to that class of tablets of which Leonard W. King in his excellent and interesting "History of Sumer and Akkad," page 290, says: "That his expeditions were not mere raids, but resulted in the permanent occupation of the country, is proved by a number of tablets found at Tello, which throw considerable light upon the methods by which he administered the empire from his capital at Ur. Many of these documents contain orders for supplies allotted to officials in the king's service, who were passing through Lagash in the course of journeys between Ur and their districts in Elam. The tablets enumerate quantities of grain, strong drink, and oil, which had been assigned to them, either for their sustenance during their stay in Lagash, or as provision for their journey after their departure."

The complexity of commercial life is illustrated by Tablet No. 1, which is an account extending over eight years, namely, from the first to the eighth year of Bur-Sin, inclusive, (2220-2212 B. C.). The first and last columns are too much broken to permit the complete unraveling of the account, but what is left of the numbers in the final column of sum totals shows that large quantities of barley, of "gig," and of meal are involved. Grain was the principal medium of exchange, and interest on loans, net revenues, etc., were paid in grain, which was most frequently barley.

The temple was the centre not only of religious but also of intellectual, legal, and commercial life. Any transaction which involved writing was concluded at the temple, where the scribes formed one class of the temple retinue, and it was in the temple that documents were filed. Tablet No. 2 is an inventory of the offerings brought in for the god of the city of Umma, the modern Jokha, the ancient enemy of Lagash. These offerings are enumerated in the following order, and consist of vases and bronze vessels of various kinds; butter, oil, and lard; fifty-five garments which were probably worn by the priests; ornaments and utensils made of stone; barley, wheat and dates; and a very large number of wooden instruments and utensils. Unfortunately the identification of many of these objects is impossible at the present state of our knowledge, but it is interesting to know the names of many of the objects with which an old Sumerian sanctuary was furnished.

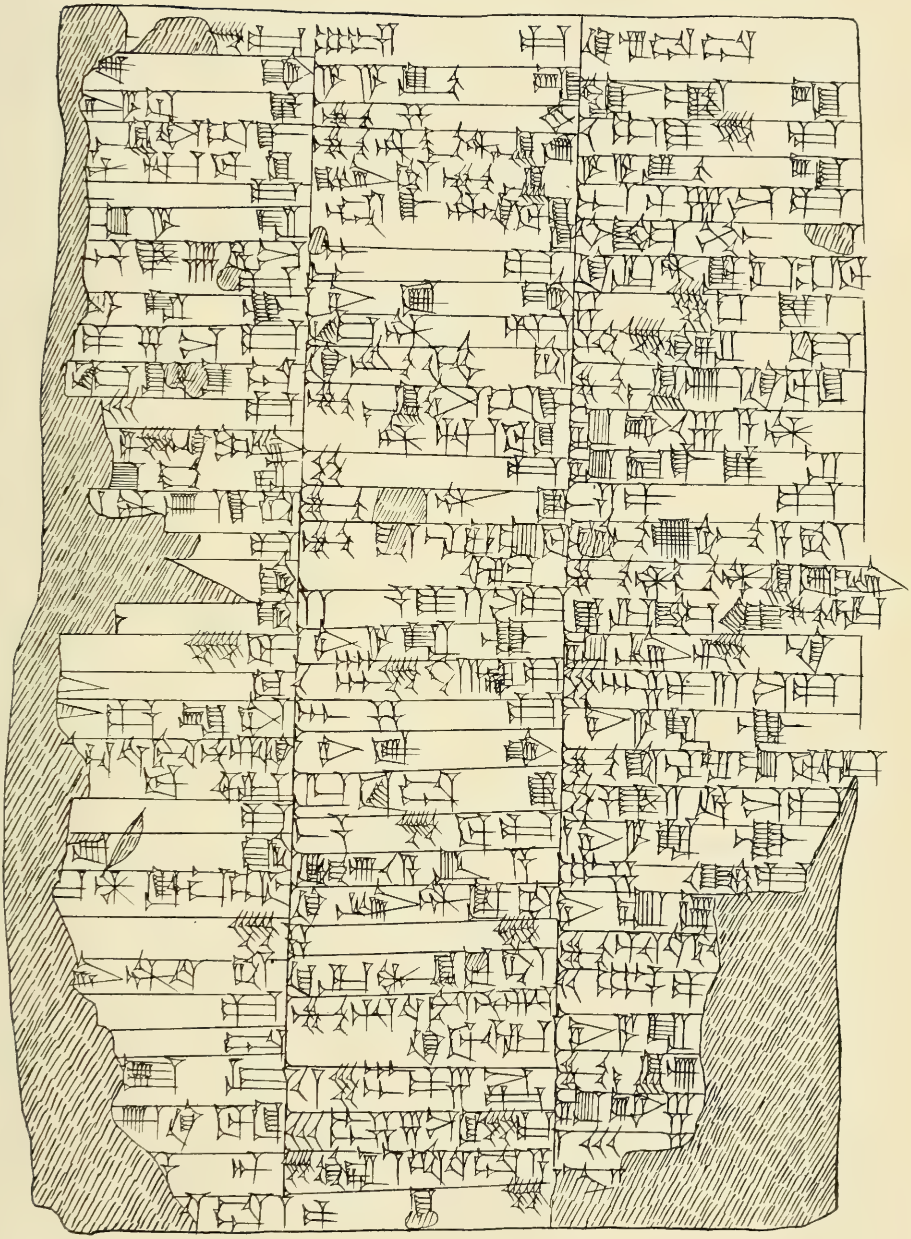
No. 4 relates to three temples in this same city of Umma, namely, the temple of the god of the city, the temple of Ninurra, and the temple of Dungi, for King Dungi introduced the innovation of the deification of the king in his own life time, and the cult seems to have been a popular one. It is an account of 314 calves taken from the stall, with the names of their respective herdsmen. Nos. 3, 7, 12, and 19 also relate to cattle and come from the modern Dréhem, a mound which is about half an hour by boat from Nippur. Large numbers of tablets from Dréhem have recently come into the market, and their decipherment shows them to be the archives of a stock farm in connection with some temple of unusual importance, presumably that of the ancient god Ellil at Nippur. No. 3 is a list of cattle, asses, and mules with the names of their herdsmen. The obverse, with the exception of the last line, is occupied with the detailed part of the account; the reverse with a summary in which the animals are enumerated and classified according to value and age. No. 7 is an account of the ewes and rams that are on hand, those taken away for sacrifice, the number of hides shorn, and number of goats. No. 12 is an acknowledgment from the butcher of eight sheep and one kid. No. 19 records the delivery of sheep and goats for sacrifice for three great festivals. The number written on the left edge of the reverse is 368, the total number of animals for sacrifice.

Connected with the temples was a large staff of persons—in the city of Lagash there were about a thousand such persons to ten temples—for whose maintenance the cultivation of large tracts of land was necessary. A more recent parallel is to be seen in the ownership and management of large estates by the monasteries during the Middle Ages. The obverse of No. 9 has been entirely erased by the scribe, but the reverse shows it to be an account of wages paid laborers working on various tracts of land for periods varying from 12 to 310 days. No. 10 is a record of provision given to ten men for the barley harvest. No. 11 records the expenditure of bread, calculated on the basis of provision for 4232 men for one day. No. 18 is a list of names of men followed by that of their overseer.

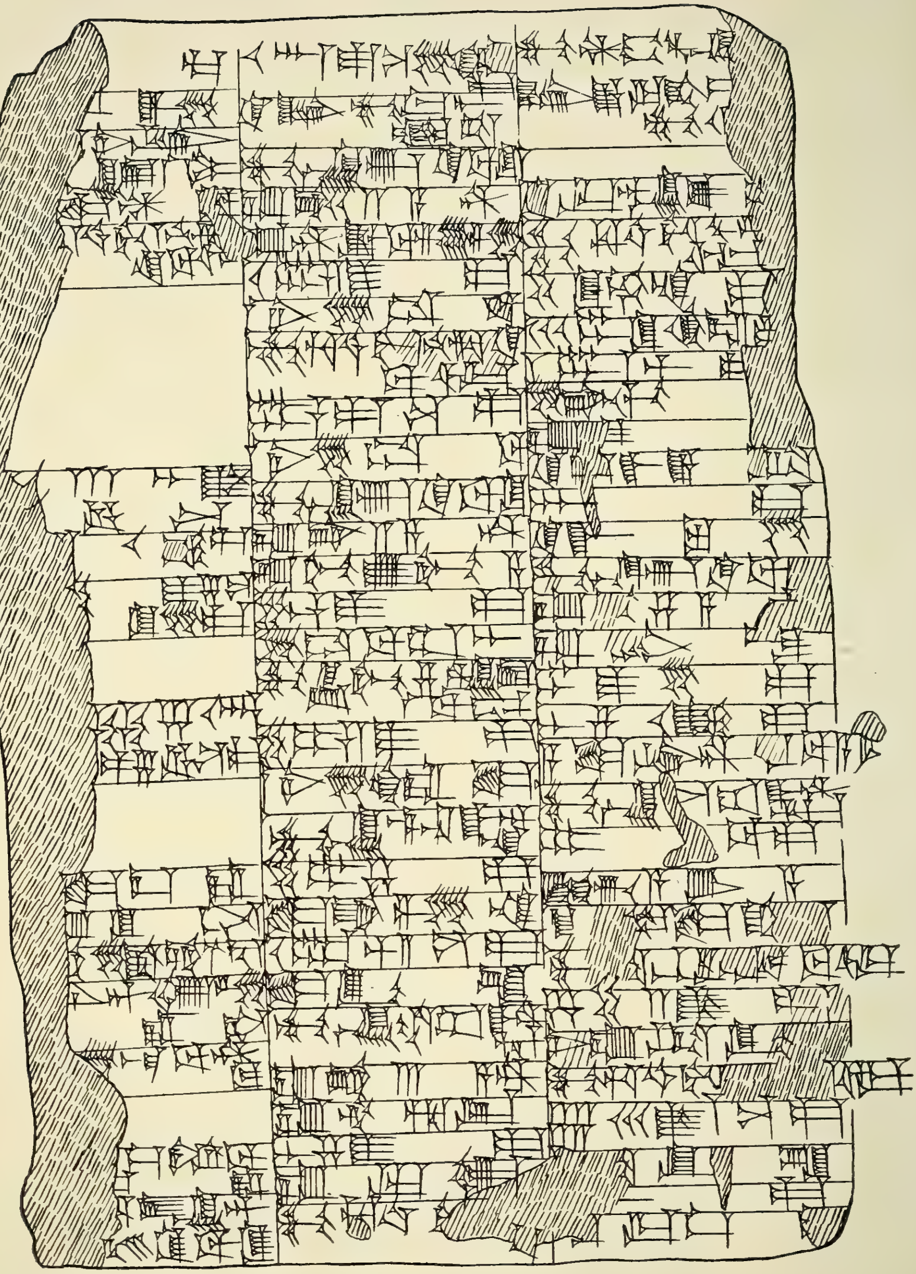
No. 6 is a record of sesame oil which is being sent to the city of Ur. No. 8 is concerning two boats whose tonnage is 20 gur, rented for six days. No. 13 is an account of various kinds of produce (dates, seed-corn, etc.) brought in for various purposes. No. 14 is a receipt for grain. No. 15 is a receipt for three bronze axes from one Akalla, presumably the smith who made them. No. 16 records the expenditure of grain for fourteen men for the new house. No. 17 is a list of quantities of butter, cheese, wool, goat's wool, sheep skins, and ox hides that have been brought into the palace. No. 20 is a receipt which incidentally gives the ratio of bronze, gold and lead to silver at the time of the first dynasty of Babylon. The line that gives the ratio of lead to silver is not quite perfect, but the ratio of bronze to silver is approximately 93½ :1, and of gold to silver 1.66 :1.

Taken singly and out of relation to the life which they record, it is of little moment to us today whether offerings were made regularly at a temple more than four thousand years ago, or whether a man with a heathen name paid his debts. We do not care how large the flocks were, whether the sesame oil was ever delivered at Ur or not, whether the rent of a boat was exorbitant or cheap, whether the ratio of gold to silver was 16 :1 or 1.66 :1, but taken collectively they are of great value. Hundreds of tablets of just this character have been published, thousands are awaiting publication in the museums of Europe and America, and tens of thousands lie buried in the mounds of Babylonia. Nor are these the only class of texts that are to be found. They are naturally the most numerous, just as in our day records of commercial transactions are more numerous than epic poems. The literature contains such works as the Gilgamesh and Creation Epics, many hymns and prayers to the gods, myths about the gods, historical texts, incantation, medical and mathematical texts and even Semitic-Sumerian dictionaries. Various studies have been made of Babylonian religion, but so far no systematic attempt has been made to reconstruct the history of the economic and social relations of the Tigris-Euphrates valley. With the awakened interest in these subjects today their importance need not be pointed out. When the social and economic history of 2300 B. C. is written, it will have to be based upon facts recorded in such tablets as these published in the following pages.

No. 1.
OBVERSE



No. 1.
REVERSE



Tablet No. 1

This is a long and complicated account extending over eight years, namely, from the first to the eighth year of the reign of Bur-Sin, inclusive (2220-2212 B. C.). Since the first and last columns—the columns of the obverse read from left to right, those of the reverse from right to left—are so much broken, it is impossible to unravel the account. Large quantities of barley, of *gig,* and of meal are involved, as what is left of the numerals in the final column of totals shows. Since grain was the medium of exchange, payments of interest, net revenues, etc., are made in grain, which is usually barley. Unbaked. Size: Length 15.7 centimeters; breadth, 11 centimeters. From Jokha.

TRANSLATION.

Obv. I, (1) .... gur of barley
.... payment of interest
.... Lunigzu
[year when] the high priest of the great sanctuary of Innana was installed.[1]

(5) .... gur
.... seal of the account.
.... 2 gur 1795 5/6 qa
.... balancing the account.
.... gur 25 qa

(10) .... Ka-shu-u-du
.... 30 gur
.... -gina son of Lueamarra
.... from [U]r-^{d}Nun-gal
.... gur

(15) .... -ga
.... -ga
.... gifts of barley
.... Lu(?)-tug
.... from [L]ukalla

(20) [the year that the city of] Huhunuri was devastated[2].
.... gur
.... payment of interest (?)
.... [U]r-x[3] the archivist.
.... barley

[1] This is the name of the 5th year of the reign of Bur-Sin.

[2] The 7th year of the reign of Bur-Sin.

[3] Name of the god of the city of Umma.

(25) . . . . from [L]u-Utu
. . . . gur
. . . . ?
. . . . úr-tuk (?)
[year when the high priest of the city of Er]idu was installed[1].
(30) . . . . an
. . . . du-du

Ob. II, (1) 9 gur 180 (qa)
net revenue
(for) four years, (namely),
from the year when Bur-Sin was made king
to the year when the great high priest of heaven was installed high priest of Nannar[2].
(5) 5 gur
payment of interest
Ka-Innana
from Shesshig
the year when the high priest of the great sanctuary of Innana was installed.
(10) 40 gur
for [U]r-X[3]
the year Shashru was devastated[4]
2 gur 142 qa
balance of the account.
(15) 17 gur of barley *har-ra*
3 gur 240 (qa)
payment of interest
Ure
1 gur 120 (qa) gift of barley
(20) the granary *a-kid-a*
from Lu-X[3]
240 (qa) of barley
from Ur-Enzu
the year that the city of Huhunuri was devastated[5]
(25) 715[6] gur 25 qa
34 gur 245 qa of barley meal
barley *har-ra lal-ta-è-a*
80 (qa) barley meal

---

[1] The 8th year of the reign of Bur-Sin.

[2] Years 1 to 4, inclusive, of the reign of Bur-Sin.

[3] The god of the city of Umma. The pronunciation is unknown. See Fr. Thurean-Dangin, Recueil de Ecriture Cuneiform, no. 458.

[4] The 6th year of the reign of Bur-Sin.

[5] The 7th year of the reign of Bur-Sin.

[6] Written: 600x60x(5x10)x5.

Ob. III, (1) from Madudu
viséd by Tabshala.
14 gur 90 (qa) of barley
net revenue.
(5) 2 gur 77 qa
ud bil gid ....
from Ur-X[1], the archivist.
Zashar, sahar[2],
interest of the interest,
(10) the year when the high priest of Eridu was installed;
the 16th account,
account of Egalesi.
1 gur 200 (qa)
from Gugu
(15) the year when Bur-Sin the king devastated the city of Urbillu[3].
account of Lugina.
53 gur 263 (qa)
balance of the account,
the year that the city of Shashru was devastated.[4]
(20) 40 gur 172 5/6 qa
balance of the account.
7 gur 240 (qa) of *gig*-grain
granary of Úr- [....]
the year when the city of Hu[hunuri was devastated.][5]
(25) 27 (gur) 140 (qa)
balance of the account,
the year when the high priest of Eridu was installed;
the 5th account.
92 [+gur....]
(30) ba[lance of the account].

---

[1] The name of the god of the city of Umma.

[2] The name of an occupation. Secretary has been suggested.

[3] The 2nd year of the reign of Bur-Sin.

[4] The 6th year of the reign of Bur-Sin.

[5] The 7th year of the reign of Bur-Sin.

Rev. I, (1) the year when Bur-Sin the king devastated the city of Urbillu.
60 (gur)
from Ur-Enzu [....]
the year that Huhunu [ril] was devastated.
(5) 40 gur of meal *gú-na*[1].
35 gur of meal *har-ra*
67 (gur) 130 (qa)
the *pal*[2] of the barley,
account ....
(10) from Egalesi.
3 gur
food for the fat sheep[3],
the year when the high priest of Eridu was installed.
account ....
(15) of Lutug.
5 gur 30 (qa) of barley
2 gur 240 (qa) of *gig*-grain
a-dug Lu-X *ba-a-gar*[4]
the year when the high priest of the sanctuary of Innana was installed.
(20) 6 gur gift of barley
granary *a-kid-a*
from Shagdugga,
the year when Shashru was devastated[2].
282 gur 50 (qa)
(25) granary Bar(?)-ta-gal
the year when Huhunuri was devastated.
510 gur 51 qa
.... *gál-la*

---

[1] *Gu-na* is the kind of meal.

[2] Meaning of *pal* is unknown.

[3] Or sheep to be fattended.

[4] The significance of the phrase *a-dug....ba-a-gar* which occurs so frequently in accounts is not yet fully understood.

[5] The 6th year of the reign of Bur-Sin.

.... gur
account of Urgish[pu].
Rev. II, (1) 13 gur 91 qa barley for interest
from Lugalmumashne
the year that the high priest of Eridu was installed,
the 22nd account
(5) the account of X[1]-baziggi.
17 gur 212 (qa)
balance of barley on hand,
the year that the city of Huhunuri was devastated.
7 gur 141 qa
(10) balance of barley on hand,
the year when the high priest of Eridu was installed,
the 2nd account
account of Gugu.
51 gur 150 (qa)
(15) barley on hand *ab-hal*[2]
the year when the bright throne of the god Ellil was made[3].
44 gur 212 (qa)
balance of the barley of interest
the year when the lofty high priest of heaven (was installed)[4]
(20) 55 gur 240 (qa)
Duggagina.
17 gur 72 (qa)
Duggalla,
the year when the high priest of the great sanctuary of Innana (was installed).
(25) 3rd account
account of Girrib.
2 gur 280 (qa)

---

[1] The god of the city of Umma.

[2] *ab-hal* is the name of an occupation or profession.

[3] The 3rd year of the reign of Bur-Sin.

[4] This part of the formula was omitted. The 4th year of the reign of Bur-Sin.

account of Ur-dun
the year Huhunuri was devastated.

Rev. III, (1) [......] gur
[......] *gé*
[......] *-ni* Lu-[^{d}]Enlilla son of [......] Ka-X[1],
[the year when H]uhunuri was devastated.
(5) [total ....6]00+(3×60)+2 gur 50 [....] 5/6 qa
[total 10 gur ....18]0 (qa) *gig*-grain
[total ......] gur 35 qa of meal
[........] 2713 gur 145 5/6 qa
[......] *dug-gà-ra* (?)[2]
(10) [......] for meal
[........] *li-bi tar-hu*
[......] from Lu-Dungi
[......] *she-na ba-an-shu*
.... *gish-ni má (?) ba ....ra*
(15) [*mu-*]*ush-sa en* ^{d}[......] *esh*^{ki} *ba-shu.*

---

[1] The name of the god of the city of Umma.

[2] Lines 9-15 are subscription, but they are too much broken to be intelligible.

Tablet No. 2

This is a list of offerings brought in for the god of the city of Umma. These offerings consist of vases and bronze vessels of various kinds; of butter, oil, and lard; of 55 garments; ornaments and utensils made of stone; of barley, wheat, and dates; and of a very large number of wooden instruments and utensils. At present it is impossible to identify all of these objects, but such a list of the objects with which an old Sumerian temple was furnished is valuable for a knowledge of the ritual. Unbaked. Undated. Size: length 14.8 centimeters, breadth 5.8 centimeters. From Jokha.

Ob. (1) 1 vase weighing 17 mana[1]
5 bronze *gal*
1 bronze *za-hu-um* vessel[2]

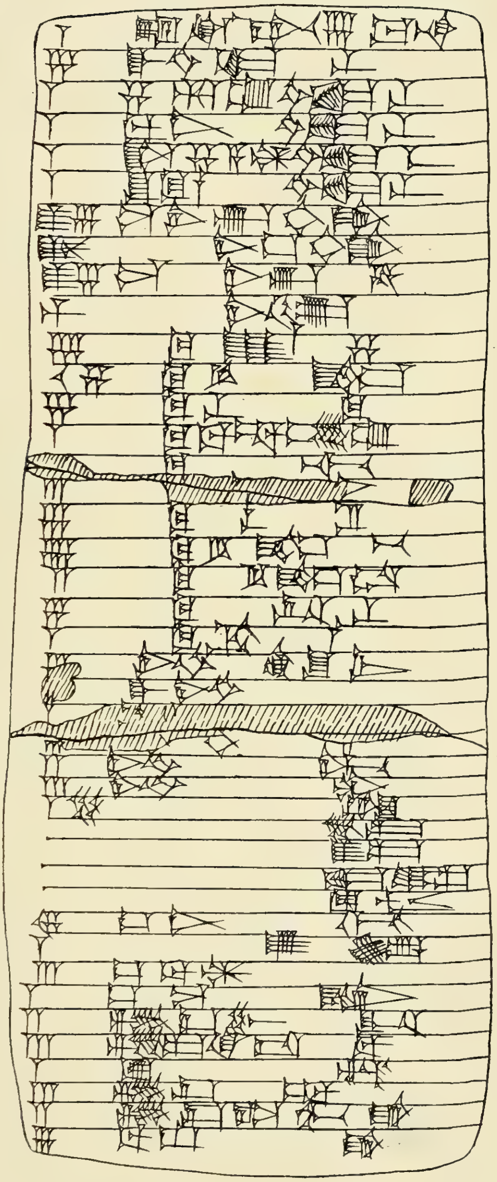
---

[1] The 17 mana is the weight of the metal out of which the vase was made, which was probably bronze.

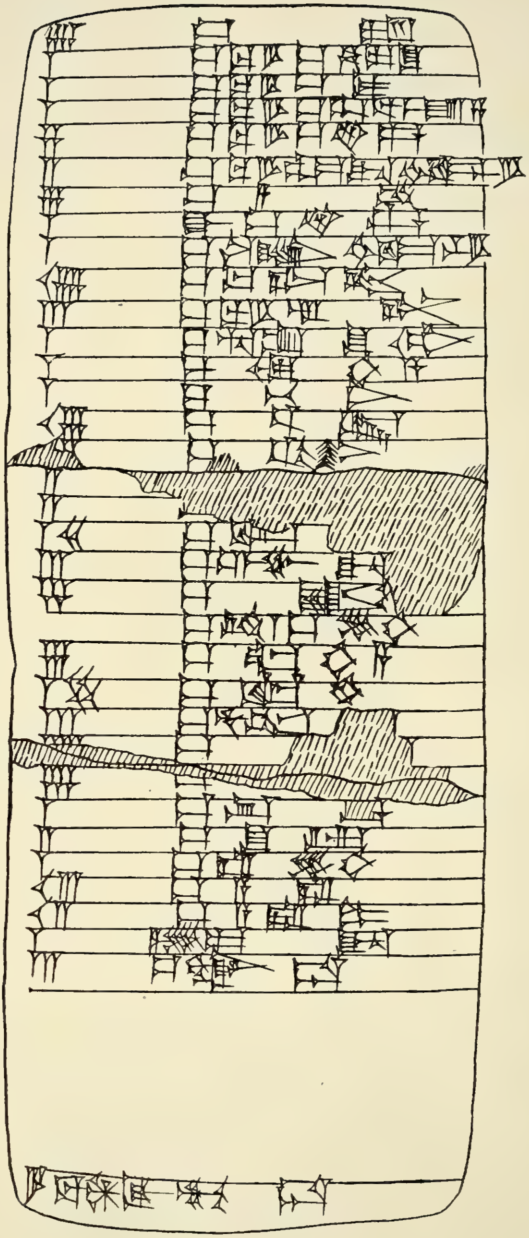
[2] Its use is unknown.

PLATE 3.

No. 2.
OBVERSE



No. 2.
REVERSE



1 bronze *dúr-rú* vessel[1]
(5) 1 bronze *sha-za-a-an* vessel
1 bronze *shu-ku-la* vessel
46 qa of excellent butter
50 qa of excellent sesame oil
45 qa of fish oil
(10) 10 qa of lard
1 *lum-za* garments[2]
14 new garments
5 *bar-tug* garments[3]
1 *ba-tab-ba gab-mes* garment[3]
(15) (?) *bal* garments[3]
3 . . . .
6 girdles
8 new garments for the dead
2 ordinary new garments
(20) 5 woven garments
1 *gú-lal* garment[3]
5 (?) stone bracelets[4]
[. . . .] *gal* of stone
1 . . . .
(25) 6 (?) . . . .
2 nagaru of stone
3 stone daggers
110 (qa) of malt
gur of barley[5]
(30) gur of wheat
gur of dates
goats-wool
14 bright bolts
1 crown
(35) 3 objects made of wood[6]
1 imperial-qa measure
2 broad baskets made of reeds
1 common-gur measure made of reeds
1 *su-nam* (?)
(40) 1 reed basket *tab-ba* (?)

---

[1] These vessels were sometimes used for wine.

[2] These garments are frequently mentioned, but the translation is unknown.

[3] The kind of garment is unknown.

[4] A bracelet or ring made of semi-precious stone.

[5] The numerals giving the quantity of grain and wool were omitted by the scribe.

[6] I know of no other place where this word *gish ba-an* occurs.

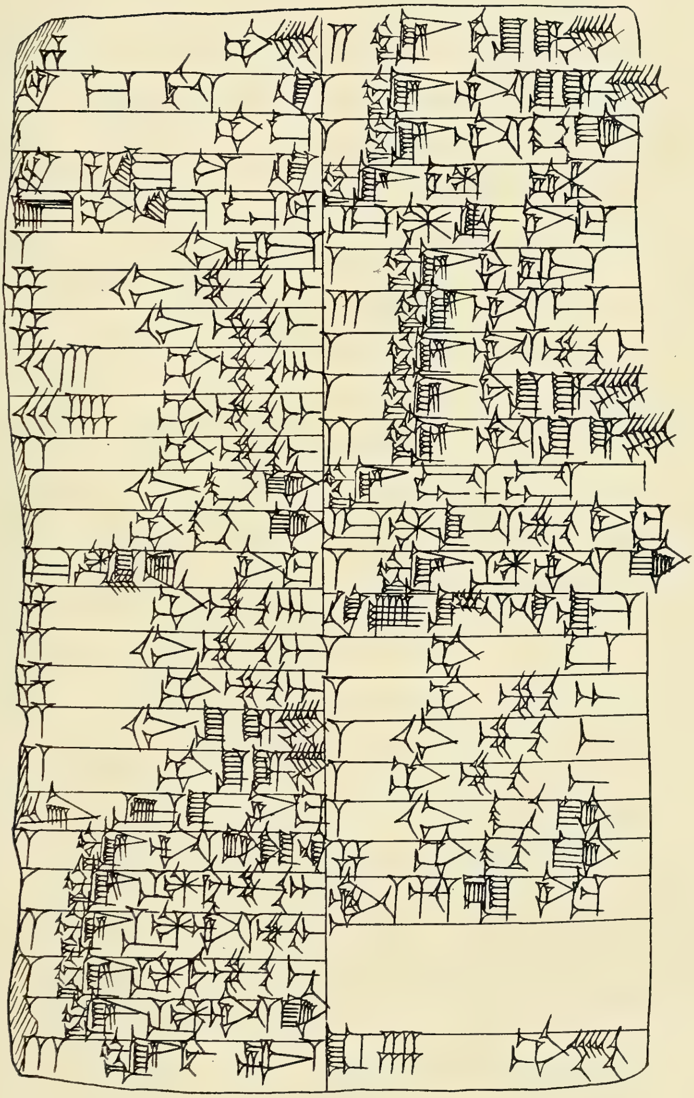
2 reed baskets *al-gu-ga* (?)
6 *ba-urudu-ga*
Rev. (1) 9 (?) wooden vases
1 throne of *ha-lu-úb* wood
1 throne of cedar wood
1 throne of *ab-ba-me sukkal-za* wood
(5) 4 thrones of *shaggullu* wood
2 thrones with the *bad-da* overlaid with copper
6 wooden *a-am* vessels
1 *gal* of *shaggullu* wood
1 imperial-qa measure made of wood, overlaid with bronze
(10) 18 wooden maltum vessels
3 thrones from Magan (?)
1 wooden *hu-um shu-ul*
1 wooden *u-dug-a*
1 wooden *bad-du*
(15) 16 axes
14 (?) vessels of tamarisk wood
2 . . . .
2 wooden . . . .
80 wooden drinking (?) [. . . .]
(20) 3 wooden *erikku* vessels
5 wooden beds
grape vine and *gish she-dug*
6 pomegranates (?)
100 wooden tongues (?)
(25) 3 [. . . .] of *nu-ùr-ma* wood
9 (?) wooden . . . .
7 wooden . . . .
1 wooden *gan-kal* (?)
2 wooden *shu-ib* utensils
(30) 1 good wooden *ra-she* utensil
13 wooden *a-ra* utensils
12 small wooden *a-ra* utensils
1 reed *gur-da* utensil
3 wooden ass goads (?)[1].
(35) Offerings of the god X[2] which were brought in.

---

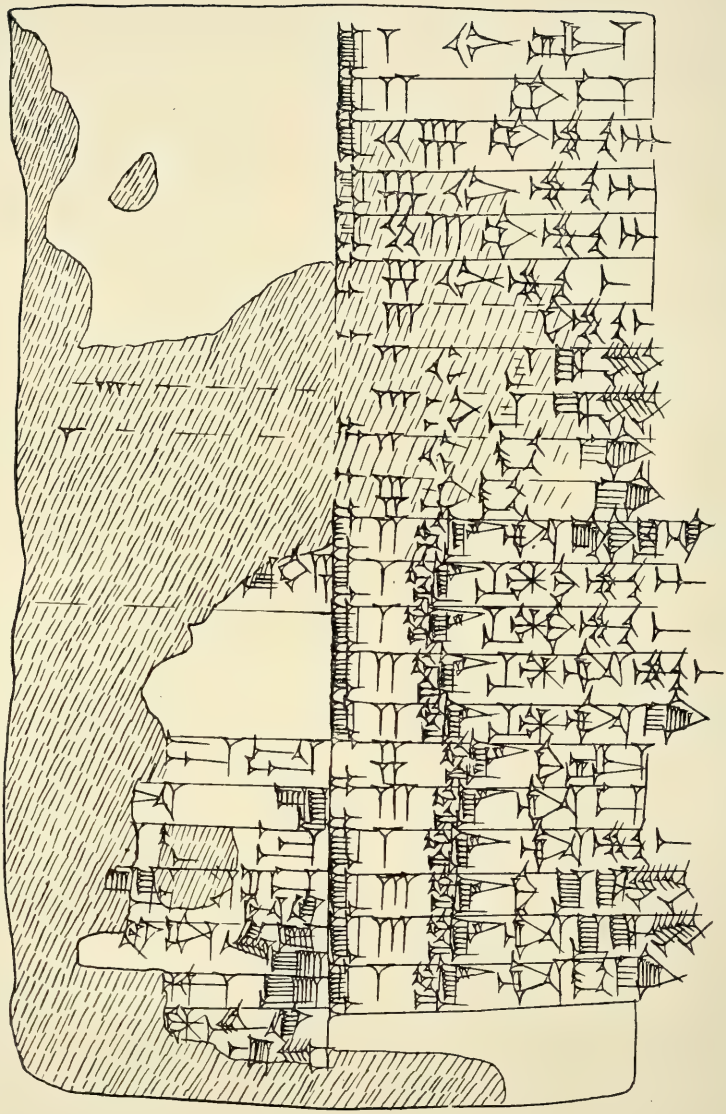
[1]. Literally, a wooden instrument for making the asses go.

[2]. The name of the god of the city of Umma.

No. 3.
OBVERSE



No. 3.
REVERSE



Tablet No. 3

The subscription, which corresponds to the heading of a modern document, is almost entirely broken away. The names of the patesi of the city of Umma, of two ministers, and of a scribe are partially legible. Although much broken, the date appears to be that of the 8th year of the reign of Bur-Sin, King of Ur (about 2212 B. C.)

This tablet is a list of cattle, asses, and mules with the names of their respective keepers. The detailed part of the list is followed by a summary in which the animals are enumerated apparently in order of value. Where the numbers in the detailed part are partially broken, they can be supplied from the summary, and vice versa. The auditing of this account shows it to be correct. Size: length 14.3 centimeters, breadth 8.2 centimeters. From Dréhem.

TRANSLATION.

Ob. I, (1) 8 fat bulls
in (the city of) Umma,
1 work-ox
in the city of Akaqa
(5) are present in the stall.
1 full-grown cow
4 heifers 2 years old
4 heifers 1 year old
23 bullocks 3 years old
(10) 38 bullocks 2 years old
2 bullocks 1 year old
1 female calf
1 male calf
Ur-enzu has (them) in charge.
(15) 4 bullocks 3 years old
2 heifers 2 years old
4 bullocks 2 years old
2 old cows
3 old bulls
(20) Luibgal has (them) in charge.
2 male asses of the desert
1 female mule 2 years old
2 male mules 1 year old
1 male mule 1 year old
(25) 1 mule-colt
3 full-grown female asses

Ob. II, (1) 2 old female asses
1 old male ass
1 ass-foal (of?)
a mother-ass
(5) Ur-X[1] has them in charge
1 full-grown female ass
3 male work-asses
1 male ass 1 year old
1 old female ass
(10) 2 old male asses
asses present
Ur-Damu has (them) in charge.
1 mule colt
from Uana, husbandman.
(15) 1 work-ox
1 bullock 2 years old
1 heifer 1 year old
1 bullock 1 year old
1 female calf
(20) 4 male calves
Arad-hug has (them) in charge.
Total 8 fat bulls

Rev. I, (1) Total 1 full-grown cow
Total 2 work-oxen
Total 27 bullocks 3 years old
Total 6 heifers 2 years old
(5) Total 43 bullocks 2 years old
Total 5 heifers 1 year old
Total 3 bullocks 1 year old
Total 2 old cows
Total 3 old bulls
(10) Total 2 female calves
Total 5 male calves
Total 2 male asses of the desert
Total 1 female mule 2 years old
Total 1 female mule 1 year old
(15) Total 2 male mules 1 year old
Total 2 mule-colts
Total 4 full-grown female mules
Total 3 male work-asses
Total 1 male ass 1 year old
(20) Total 3 old female asses
Total 3 old male asses
Total 1 ass-colt

---

[1] The name of the god of the city of Umma.

Rev. II, 1[1] ....
....
....
....
(5) ....
....
....
Al -la patesi of the city of Umma
[....]-sag-ta-azag-su, minister
(10) [....]-Innina, minister
[....]-Nannar, scribe
The year when the high priest, beloved of Bur-Sin was installed (?) the high priest of the city of Eridu.

---

[1] Lines 1-4 are entirely broken away. The subscription begins with line 5, which, with the two lines following, is too much broken to be read.

Tablet No. 4

An account of 314 calves belonging to the temples of the god of the city of Umma, to the temple of the gods Nin-ur-ra and Dungi, which were taken from the stall. The character with which the name of the month is written has not been identified[1] but it is known to be the fourth month in the calendar of JOKHA. The name of the year is new, and it has therefore not been classified. Size: 10.5 centimeters by 5 centimeters. From Johka.

TRANSLATION.

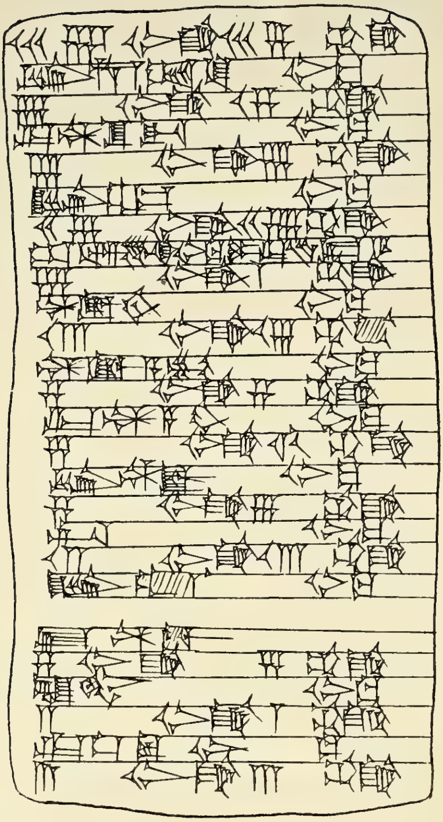
Ob. (1) 37 female calves, 35 male calves
Lu-Ninni-Unu(g)^{ki}, herdsman.
8 female calves, 14 male calves
Ur-Sida, herdsman.
(5) 7 female calves, 7 male calves
Lugalezen, herdsman.
26 female calves, 28 male calves
Abbagina, herdsman, son of Urnigingar.

---

[1] No. 63 in Scheil, *Recueil de Signes.*

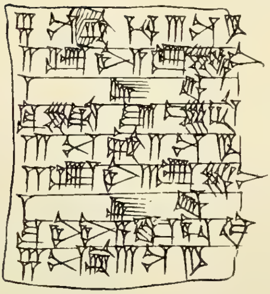
No. 4.

OBVERSE



No. 5.

OBVERSE



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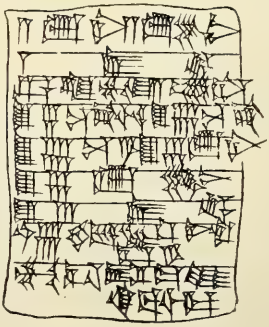
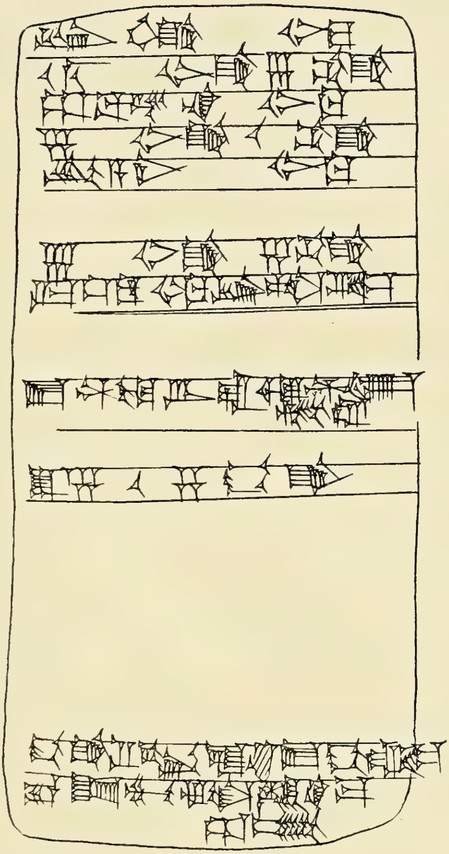


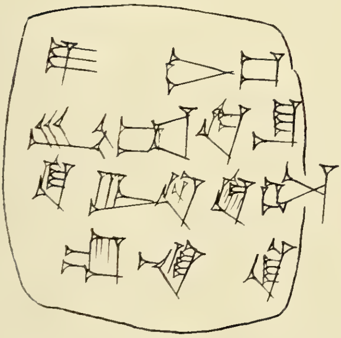
PLATE 8.

No. 4.
REVERSE

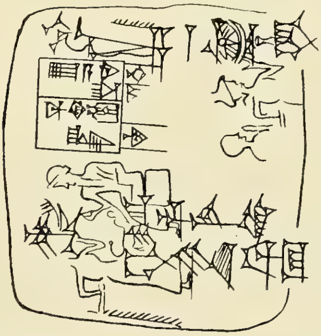


No. 6.

OBVERSE



REVERSE



7 female calves, 1 male calf

(10) X[1]-kam, herdsman.
13 female calves, 16 male calves
X[1]-a-mu, herdsman.
4 female calves, 4 male calves
Ur-Adin, herdsman.

(15) 5 female calves, 9 male calves
Lu-X[1], herdsman.
4 female calves, 6 male calves
Nita, herdsman.
12 female calves, 13 male calves

(20) Lugal-ezen (?), herdsman.
Temple of the god X ([1]).
4 female calves, 5 male calves
Lalul, herdsman.
2 female calves, 1 male calf

(25) Urgishpu, herdsman.
3 female calves, 3 male calves

Rev. (1) Ludugga, herdsman.
9 female calves, 6 male calves
Abbagina, herdsman.
5 female calves, 10 male calves

(5) Sheshani, herdsman.
7 female calves, 5 male calves
Urgishpu, herdsman, servant of the patesi.
Temples of Ninurra and of Dungi.
Total of 314[2] calves

(10) Calves taken from the stall.
Month of X[3], the year when the bark of the god Enki was built (?).

---

[1] The name of the god of the city of Umma.

[2] The actual total is 317 (!)

[3] No. 63 in Schell, *Recuil de Signes*

Tablet No. 5

Provision list of three men, dated in the 4th year of Gimil-Sin, King of Ur (about 2201 B. C.). The name of the month corroborates the statement of the dealer, that this tablet came from JOKHA. Unbaked. Size: length 3.5 centimeters, breadth 2.8 centimeters. From Johka.

TRANSLATION.

Ob. (1) 5 qa[1] of first-quality wine, 3 qa of bread
2 sheckels of oil, 2 sheckels of grain.
1 bag of (?)
for Kuli, minister.
(5) 3 qa of wine, 2 qa of bread,
2 sheckels of oil, 2 sheckels of grain,
1 bag of (?)
Gimil-ili.

Rev. (1) 5 qa of wine, 3 qa of bread,
2 sheckels of oil, 2 sheckels of grain,
1 bag of (?)
for Kallamu, minister.
Total 5 qa of first-quality wine. Total 5 qa of (ordinary) wine.
(5) Total, 8 qa of bread. Total 6 sheckels of oil.
Total 6 sheckels of grain. Total 3 bags of (?).
The 7th day of the "month when the bricks are put in the mill,"[1] the year after the devastation of the City of Simanu.

Tablet No. 6

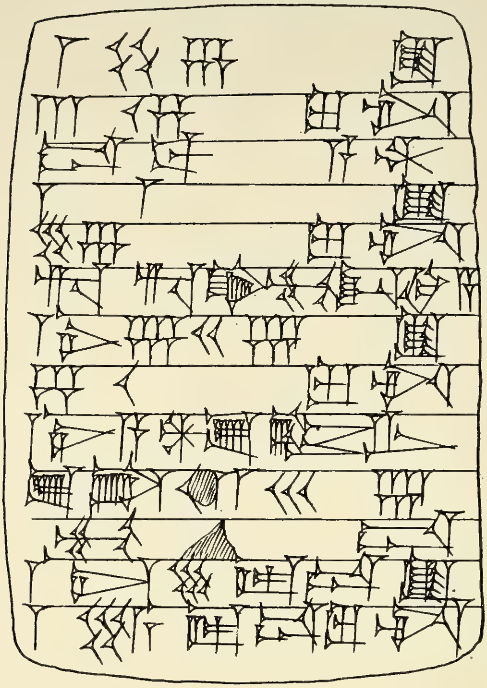
An account of sesame oil which is being sent to (the city of) Ur by Tukshagki, charged to Nadi, viséd by Ahuwaqar. The tablet is dated in the dynasty of Ur, but the exact year of the dynasty has not yet been determined. The eight impressions of the seal, no one of which is perfect, have almost obliterated the writing. The scene of the seal is one of presentation. On the right is a god seated upon a throne, a turban is on his head, and in his right hand he is holding a goblet aloft. In front of him is a star within a crescent, and two figures. The first of these figures,

---

[1] This is the second month in the calendar at JOKHA, namely, the month of Sig gir i-sub ga-gar.

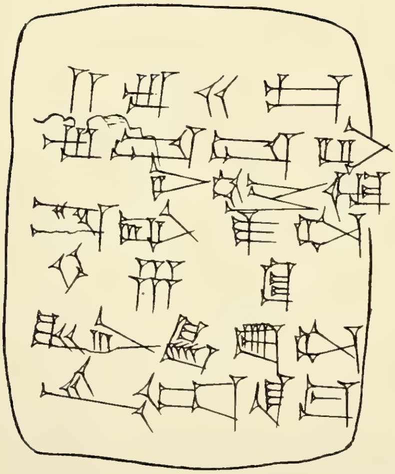
No. 7.

OBVERSE – REVERSE BLANK

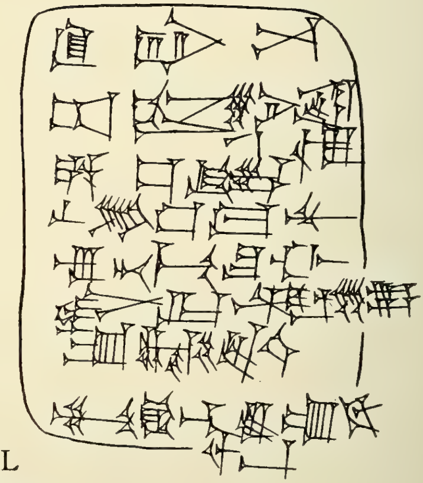


No. 8.

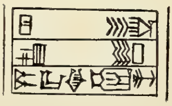
OBVERSE



REVERSE



SEAL



is a goddess, clothed in a long garment and a cap with two horns, who is presenting to the seated deity a man with uncovered head who is wearing a fringed garment. The inscription on the seal reads: (To) E-a-ni-sha, priestess beloved of the King, Na-di son of [....], thy servant. Baked. Length 4 by 3.7 centimeters.

TRANSLATION.

Ob. (1) 30 (qa) of sesame oil
(which is being sent) to the city of Ur
by Tukshagki,
the seal of Nadi,

Rev. (1) viséd by Ahuwaqar.
The year in which the high priest of the god
Nannar was installed (?) in Gĕsh.

Tablet No. 7

This is a report concerning the flocks, but contrary to the usual custom, no shepherd's name is given. Unbaked. Undated. The form of the writing shows that it comes from the dynasty of Ur. Size: Length 8.8 centimeters, breadth 5.8 centimeters. It is said by the dealer to have been found in the modern Senkereh, the ancient Larsa or Biblical Ellasar of Genesis 14.1.

TRANSLATION.

Ob. (1) 106 ewes
194 rams
are on hand.
61 ewes
(5) 56 rams
have been taken away, offered in sacrifice (?).
There remain 447 ewes
310 rams.
There remain hides that have been shorn,
(10) (the number of) their hides 757[1]
are on hand.
There remain 120 kids running with the ewes.
109 kids running with the rams.

---

[1] Note that this is the sum of the two preceeding lines.

Tablet No. 8

Concerning two boats whose tonnage is 20 gur, its rent 30 qa for six days. There are some twenty-three impressions of the notary's seal, which almost obliterate the writing. The seated figure of a god is partially discernable. The inscription on the seal reads: Kuli, scribe, son of Urkiagmu. The tablet is dated in the X+40th year of the reign of Dungi (about 2240 B. C.). Baked. Size: length 5.6 centimeters, breadth 4.5 centimeters.

Translation.

Ob. (1) 2 boats of 20 gur
boats whose presence(?) is *ni-ib* and
whose rent is 30 (qa)
for 6 days,
(5) (payable) to Lugalazagzu
(going to) the city of Ur.

Rev. (1) *shú-bi-qa*
ésh-ib-in-su and
kir of palm,
branches of cedar
má-pal-shu-ag (?).
Viséd by Ur-Ezinu
seal of Namshatam.
The year when the city of Shashru was devastated.

Tablet No. 9

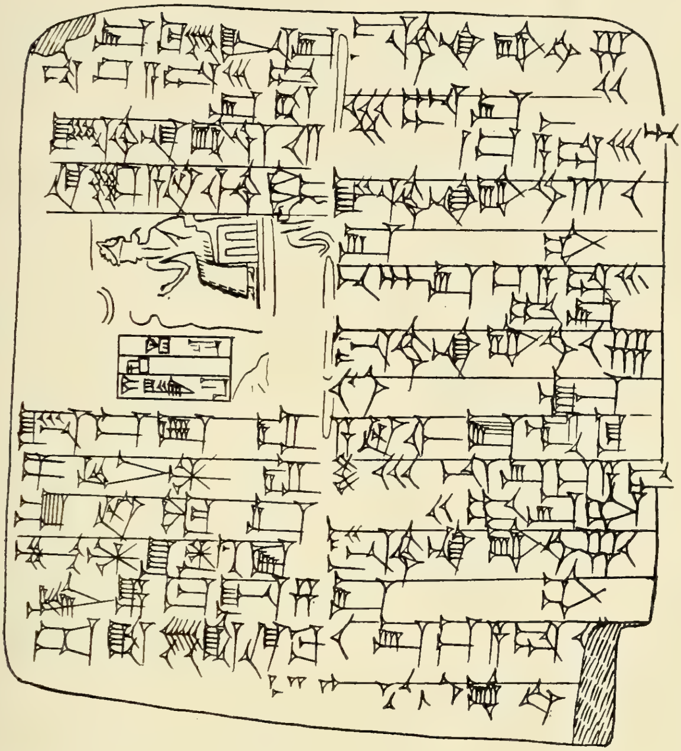
The obverse has been written and then entirely erased. The reverse is almost unintelligible owing to the erasure of the obverse and because it has been made almost illegible by the seal of the notary having been run over the entire surface. The seal represents a god seated on a throne, before whom is a crescent. The figure of the worshipper is out of position because two seal impressions have been run together. It reads: Shaningish, scribe, son of Lugalla.

The account is in regard to the wages of laborers for working on a certain quantity of land. It is dated in the 7th year of the reign of Gimil-Sin, King of Ur (about 2203 B. C.). Baked. Size: length 9 centimeters, breadth 8.1 centimeters.

PLATE 10.

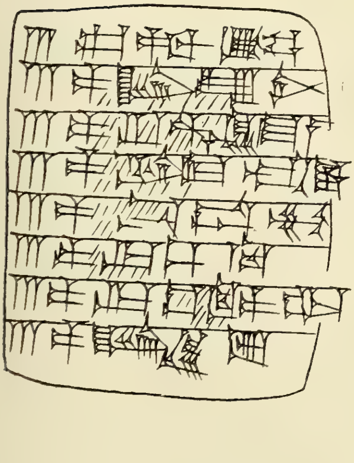
No. 9.

REVERSE — OBVERSE ERASED BY SCRIBE

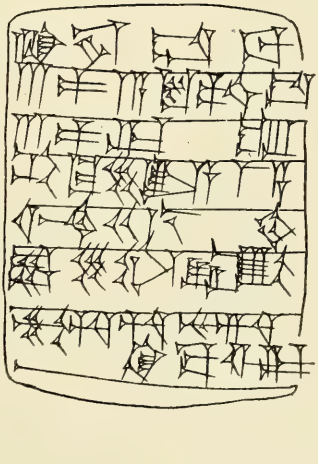


No. 10.

OBVERSE



REVERSE



TRANSLATION.

Obverse Wanting.

Rev. I, (1) Wages of the laborers (for) 300 days.
5+5/8+1/36+1/72 of a gan[1] park land
for ...... ;
Wages of the laborers (for) 190 days,
ploughed land.
(5) 1/3+3/18 of a gan park land to
3+4/18+1/36 of a gan ......
Wages of the laborers for 18 days,
food for the farmers,
for the field *igi+é-mah.*
10+3+1/18+1/36+1/72 of a gan park land
to 2+4/18+1/36 of a gan
(10) Wages of the laborers for 310 days
ploughed land.
1 gan of park land to ....
Wages of the workmen for .... days.

Rev. II, (1) ...... gan ......1/36+1/72 of a gan park
land to 2+4/18+1/36 of a gan.
Wages of the laborers for 12 days
from the park, the excellent small field.
Wages of the park land,
(5) Overseer, Ludingirra,
seal of Shaningish.
The year in which Gimil-Sin, the King, devastated the land of Zabshali.

Tablet No. 10

Distribution of (grain) to ten different men for the oxen during the barley harvest. Since the name of the month follows the nomenclature used at Umma (the modern Jokha), we infer that the tablet came from that place. It bears the date of the 7th year of Bur-Sin, King of Ur (about 2211 B. C.) Size: length 5 centimeters, breadth 3.9 centimeters.

---

[1] The gan is the unit of land measure.

TRANSLATION.

Ob. (1) 3 (gur) 20 (qa) (to) Bashag
3 (gur) 20 (qa) (to) Lugalukkinni
3 (gur) 20 (qa) (to) Ur-Enlilla
3 (gur) 20 (qa) (to) Lugalemahe
(5) 3 (gur) 20 (qa) (to) Dadumu
3 (gur) 20 (qa) (to) Urgishpu
3 (gur) 20 (qa) (to) Urgishpu the diviner (?)
3 (gur) 20 (qa) (to) Lugalazagzu
Rev. (1) ....gub-ba
3 (gur) 20 (qa) (to) Idpae
3 (gur) 20 (qa) (to) Urmes;
weighed out for the oxen of the barley harvest
(5) before the workmen on the 19th
of the month Shekarragal,
the year that Huhunuri was destroyed.

Tablet No. 11

Expenditure of bread in payment of 4232 laborers. Only the obverse is inscribed, but the reverse has been written on, probably in making some calculation, since the numbers 240, 20, etc., are still legible. Undated. Baked. Size: length 9 centimeters, breadth 6.2 centimeters.

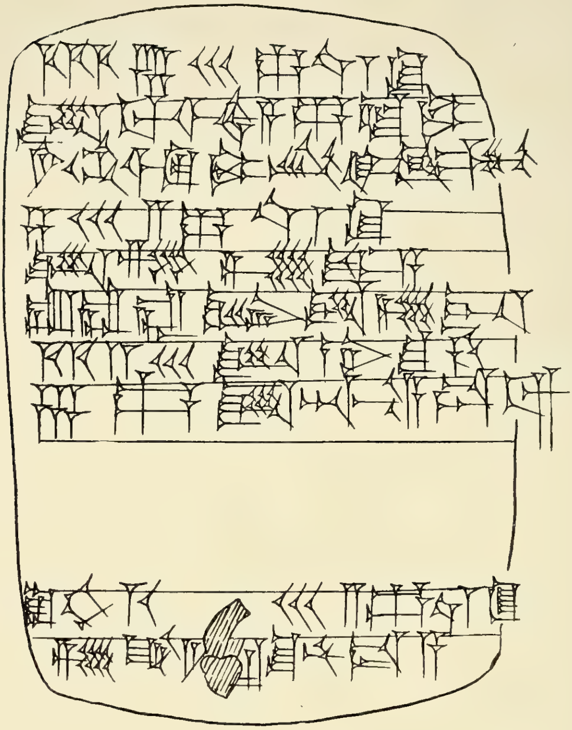
TRANSLATION.

Ob. (1) 2250[1] laborers for one day
payment, Bashag, Akalla son of Nigdu and son of Sheskiagmu.
272[2] laborers for one day,
payment, Gizi, *sig-a*[3].
(5) Sealed with the seal of Lugalazida.
1350[4] laborers, payment Lallishuza.
360[5] laborers, payment Palaguba.
Total 4232[6] laborers for one day.
Expenditure of bread *shu-nu gub-ba*.

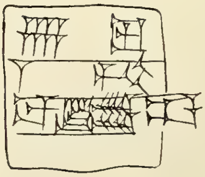
---

1. Written: (3x600) + (7x60) + (3x10).
2. Written: (4x60) + (3x10) + 2.
3. Meaning unknown.
4. Written: (2x600) + (2x60) + (3x10).
5. Written: (6x60).
6. Written: 3600 + (3x10) + 2.

No. 11.
OBVERSE — REVERSE BLANK



No. 12.
OBVERSE
REVERSE BLANK



Tablet No. 12

An undated receipt. The form of the writing shows that it comes from the perio dof the dynasty of Ur (2300-2300 B. C.). Size: Length 2.2 centimeters, breadth 2 centimeters.

TRANSLATION.

Ob. (1) 8 sheep,
1 goat,
Bashag the butcher (?).

Tablet No. 13

An account of quantities of [....], dates, seed-corn, etc., brought in by various persons. The scribe has erased three lines after having written them (namely, Obverse 1, 8, 9), and the numerals and a part of the proper names in five other lines, so that it is impossible to understand the account. It is dated in the X+37th year of Dungi (i. e. about 2241 B. C.). Baked. Size: Length 7.6 centimeters, breadth 4.7 centimeters.

TRANSLATION.

Ob. (1) 3 sheckles................[1].
5 sheckles from Uremah, door-keeper.
[....] sheckles in payment of interest from Ur-dun.
............[2] HA-MUN from Nau.
(5) 3 sheckles from Urgishpu, bird-catcher.
3 sheckels from Lugalmagurri.
5 sheckles from Babila.
[..........][2]
[..........][2]
(10) [........][1] Azag-gu from the *gal-li*[3] of the new house.

Rev. (1) [......][2] 1/5 from Lugalazida,
[......][2] from Aradhula,
[......][2] shekels minus 1/180 of a shekel from Nigdule,

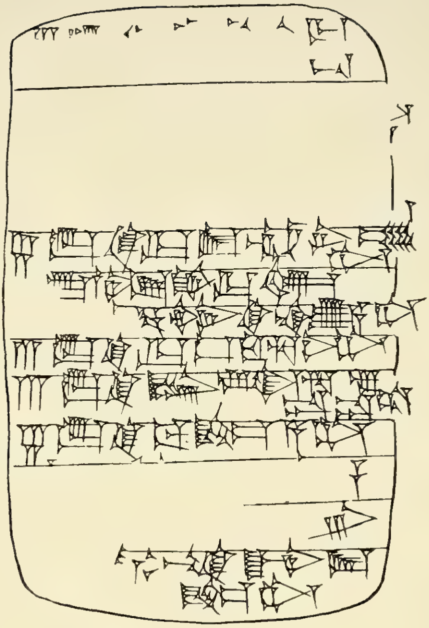
---

[1]. The rest of the line has been erased, likewise the space between the first and second line has been written over and erased.

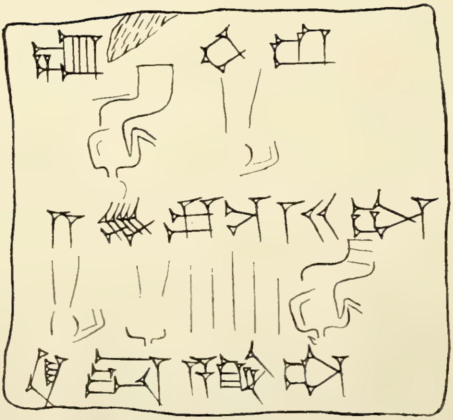
[2]. Erasure.

[3]. *gal-li* is the name of a profession or occupation of which the translation is unknown.

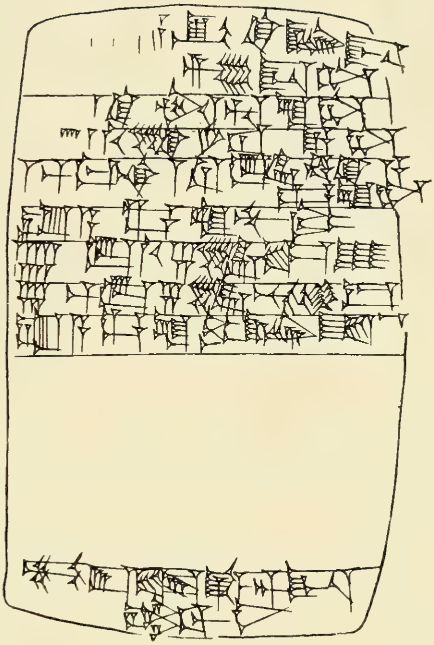
No. 13.
OBVERSE



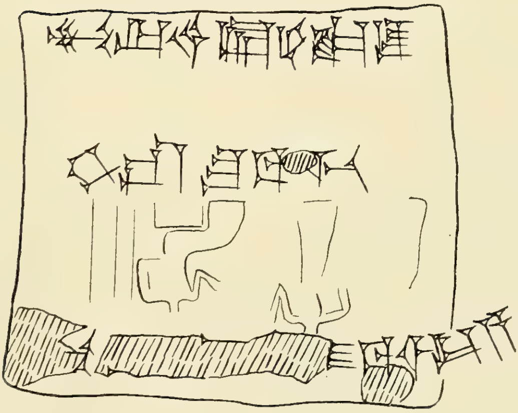
No. 14.
OBVERSE



No. 13.
REVERSE



No. 14.
REVERSE



1½ mana 1 2/3 shekel of light-colored
A+HA[1] from Akalla,
(5) charged to Akalla, overseer[2].
9 shekels minus 1/12 of a shekel of light-colored dates,
8½ shekels plus 1/36 of a shekel of light-colored seed-corn,
charged to Akalla, the son of Lugal-X[3]-e,
The year when the temple (named) Ebashaish-Dagan[4] was built.

Tablet No. 14

This is what is called a case-tablet, i. e. a tablet which is in a clay case or envelope. These tablets are recognized as case-tablets by their size and shape, or by the rattling of the inside tablet which can sometimes be heard if the tablet is shaken gently. The case has been securely sealed, having two seal impressions on both the obverse and the reverse, and one impression on each of the four sides. The seal impression is too faint to be read, but a god seated on a throne into whose presence a worshipper is being led by another god or goddess (?) is faintly discernible. In all probability it is the seal of Dugri. The tablet is unbaked, and so much of the date is broken that the year cannot be determined exactly. It comes from the period of the dynasty of Ur (300-2200 B. C.). Size: Length 5 centimeters, breadth 5.5 centimeters.

Translation.

Ob. Seal of Dugri.
2 gur of barley to qa 80
(brought in) by Daaga
Rev. on behalf of Urnigingar,
Dugri has received (it).
The year that the city of [......] was devastated.

---

[1] meaning of this sign is unknown. It is listed in THUREAU DANGIN'S *Recherches sur l'ecriture cuneiform,* No. 471.

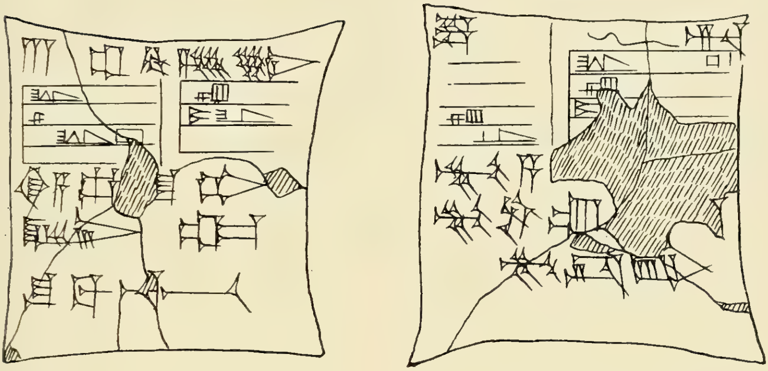
[2] The term applies to overseers of various kinds, often, as here, to an officer for collecting dues.

[3] This sign has not yet been identified. See SCHEIL, *Recueil de Signes,* No. 63.

[4] This god Dagan is identical with the Philistine god Dagan (see I Samuel 5.9-5).

PLATE 14.

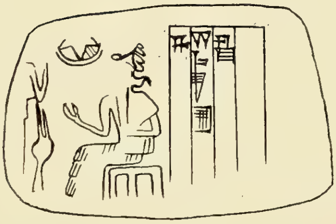
No. 15.
ENVELOPE



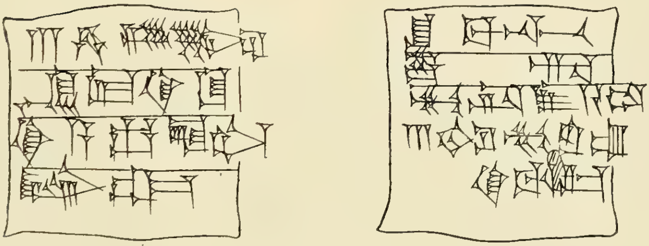
OBVERSE

REVERSE

SEAL ON ENVELOPE



INNER TABLET



OBVERSE

REVERSE

Tablet No. 15

This is also case tablet. Since the case was already cracked, it was opened for the first time in October, 1913, some 4158 years after it had been sealed. It is dated in the X+31st year of Dungi (about 2245 B. C.).

There are eight impressions of the notary's seal on the envelope, none of which is perfect. The scene is that of a god seated on a throne, before whom a vessel with a long neck and long spout is standing, while above it is a star and crescent. A god or goddess with one hand raised is approaching, probably leading a worshipper by the hand. The seal is that of Lugal-ezen, scribe, son of Lugal-e-(?), diviner (?).

This tablet is a receipt for three bronze axes, and is dated in the month Ri, the X+31st year of Dungi. This month name shows that the tablet probably came from Jokha. It is unbaked. Size of the inner tablet 2.8 centimeters, breadth 2.8 centimeters; outer tablet or envelope, length 4.2 centimeters, breadth 4.3 centimeters.

TRANSLATION OF ENVELOPE.

Ob. (1) 3 bronze axes
from Akalla
Lugalezen
has received.

Rev. (1) Month of Ri,
the year after the city of Simuru (was devastated) for the third time.

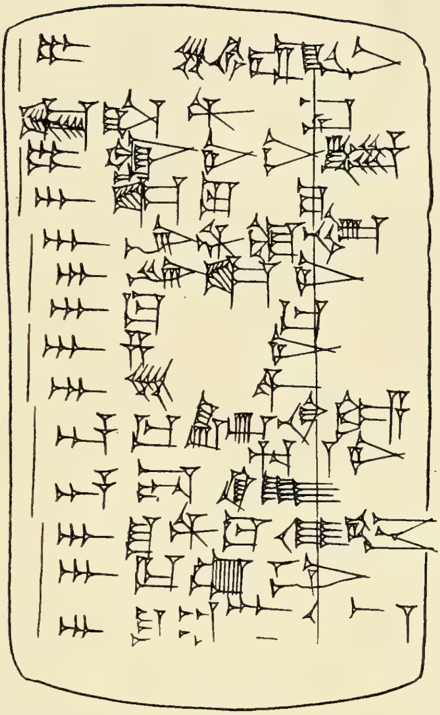
TRANSLATION OF INNER TABLET.

Ob. (1) 3 bronze axes
for Nippur
from Akalla
Lugalezen

Rev. (1) has received.
Month of Ri,
The year after Simuru was devastated for the third time.

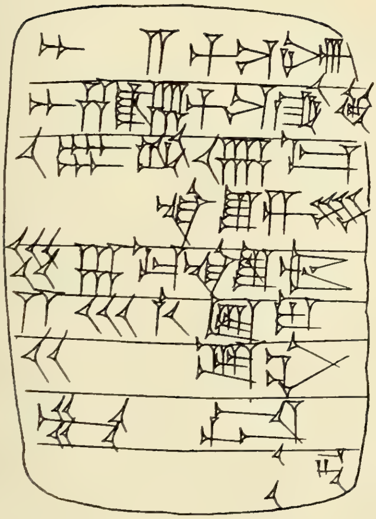
No. 16.

OBVERSE

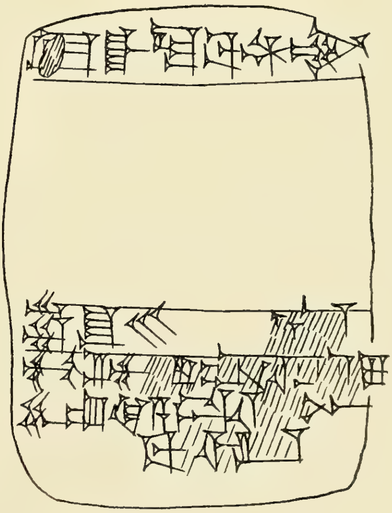


No. 17.

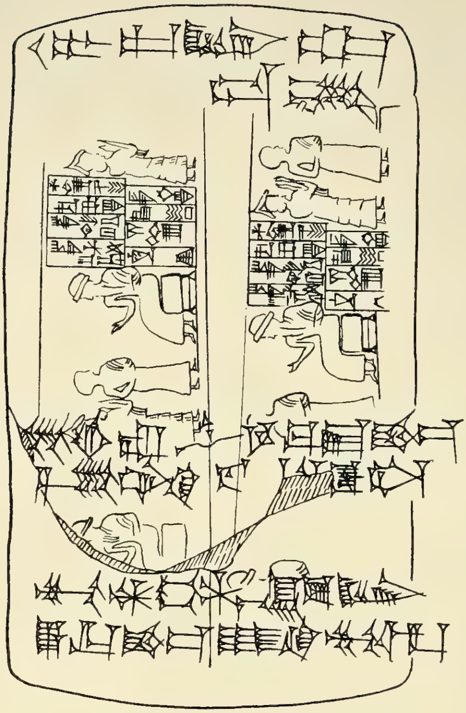
OBVERSE



REVERSE

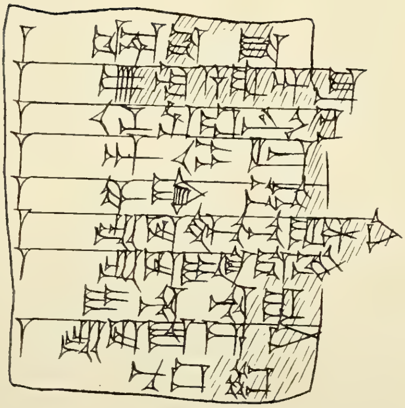


No. 16.
REVERSE

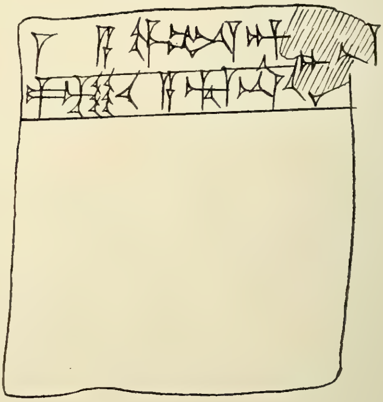


No. 18.

OBVERSE



REVERSE



Tablet No. 16

An account of the expenditure of grain for food, the 2nd year of the reign of Bur-Sin, King of Ur (about 2218 B. C.). Baked. Size: Length 8.7 centimeters, breadth 5 centimeters. The writing on the obverse is very much obscured by twelve impressions of the seal, of which there are four on the reverse. It represents a god wearing a turban, seated upon a throne, before whom a worshipper is standing. The goddess standing behind the worshipper is acting as intercessor. The seal reads: (To) Dungi, the mighty hero, King of Ur, King of the four quarters of the world, Ludugga, the scribe, son of Nigingardugga, thy servant.

TRANSLATION.

Ob. (1) 5 imperial-(gur) of grain for food,
Basha-Ishtar.
5 Girninishag[1],
3 Kaluku,
(5) 3 Lu-Ninshubur[2],
3 Lukani,
3 Mama,
3 Zani,
3 Shelim,
(10) 2 (gur) 120 (qa) Ur-azagnunna, son of Ahuni,
2 (gur) 120 (qa) Dakilum
3 Gimil-Mamitum
3 Urmes (?)
3 Gimil-ad(?)-lum-(?)-(?)

Rev. (1) 15 gur Lugalezen *du-gab*[3].
Grain, imperial measure, for food; bread for the new house,
expended by Ba-^{d}X[4]

---

[1] "gur of grain for food" is to be understood before each name.

[2] This name means, Man (worshipper) of the goddess Ninshubur.

[3] *du-gab* is the name of his occupation or profession. Its translation is unknown.

[4] X is the god of the city of Umma, but the pronounciation is unknown.

Tablet No. 17

This is a list of butter, cheese, wool, and hides that had been brought to the palace. It is lightly baked and dated in the X+42nd year of Dungi (about 2242 B. C.). Size: Length 6.3 centimeters, breadth 4.4 centimeters. It is said by the dealer to have come from the modern Senkereh, the ancient Larsa or Biblical Ellasar of Genesis 14.1.

TRANSLATION.

Ob. (1) 2 (gur) 2½ qa of butter
2 287½ qa of cheese
17 talents 18 mana of *gi*-wool
56 mana of goat's wool

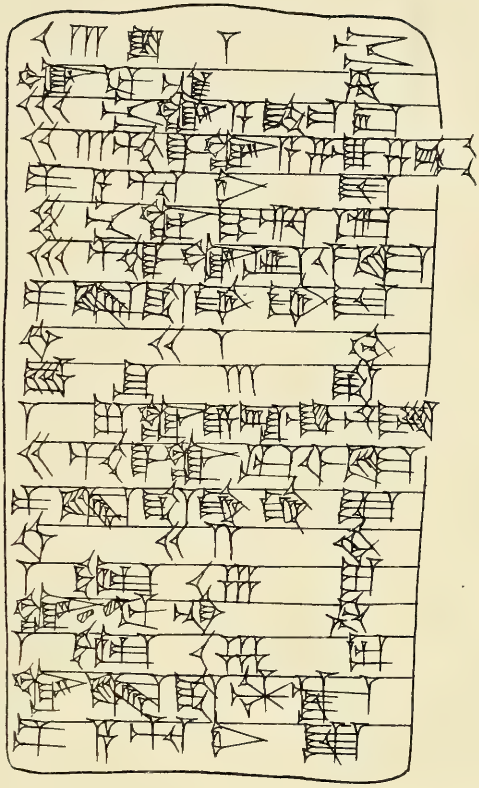
(5) 149 sheep skins
20 ox-hides
are on hand.

Rev. (1) They have been brought into the palace.
Month of Shuessha
the year that Simuru and Lulubu were completely devastated (literally, devastated for the ninth time).

Tablet No. 18

This tablet has disintegrated very rapidly owing to the crystalization of the salt contained in the tablet. It is a list of names of nine men, followed by the name of their overseer. Unbaked. Undated. The form of the writing points to the time of the first dynasty of Babylon (2060-1761 B. C.), which is confirmed by the names being largely Semitic. In the third line, Ubar means friend, the rest of the name being uncertain. The name in the fourth line is abbreviated from "May the God Milik (be favorable)". In the sixth line the name means: "The god Enzu was favorable to me." In lines seven and eight and Rev. I the names mean, "The god Enzu has presented," "The god Enzu has heard," and "Man of the god Enzu." Size: Length 4.9 centimeters, breadth 4 centimeters. It is said to have come from Senkereh (Larsa, the Biblical Ellasar).

No. 19.
OBVERSE



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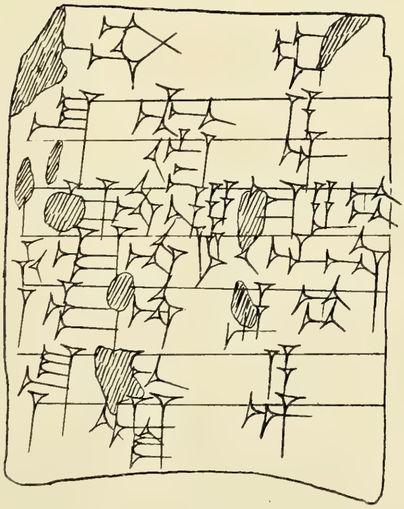
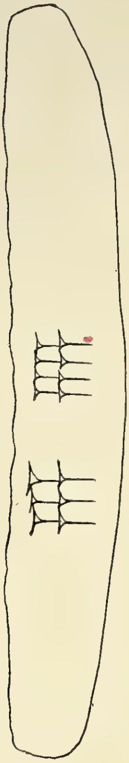


DGE.



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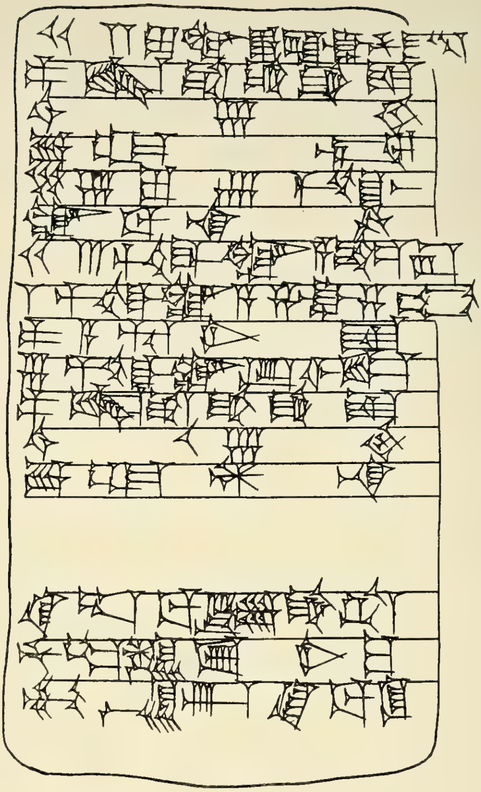
REVERSE



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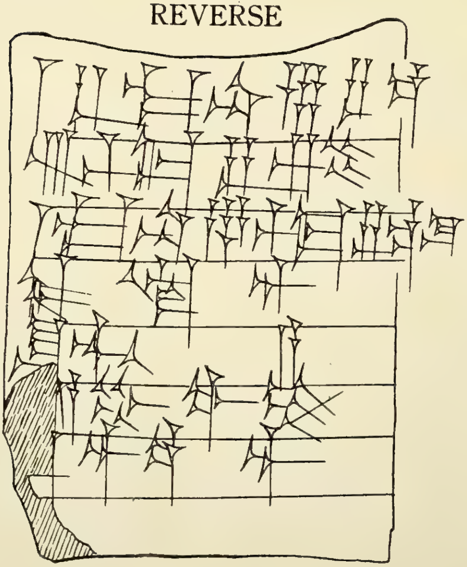


TRANSLATION.

Ob. (1) KA-sha-sha
U-la-a-ra-an-shu(?)
U-bar-ra-at(?)-SHESH-MA(?)
^{d}Mi-lik
(5) Wa-ga-qum
^{d}En-zu-im-gu-ra-an-ni
^{d}En-zu-i-ki-sha-am son of Warad-warad-ra
En-zu-ish-me-a-ni, gardener
Rev. (1) A-wi-il-^{d}En(?)-zu(?)
Superintendent, Nam-u-a-hu-na(?)-?

Tablet No. 19

An account concerning the delivery of 368 sheep and goats by one Abbashagga, an employee whose name is mentioned more frequently in the Dréhem tablets than that of any other person. The sheep and goats are (for sacrifice) on the 21st and 22nd of the month Shuessha (December); for the 7th of "the month of the great festival" (January); and for the 17th of "the month of the feast of heaven" (February). The total number of sheep and goats, namely 368, is written on the left edge of the reverse, thus: $(6\times60)+8$. This tablet is dated in the 8th year of the reign of Bur-Sin, King of Ur (about 2212 B. C.), and is unbaked. Size: length 9.7 centimeters, breadth 5.2 centimeters. It is said by the dealer to have been found at Jokha, but both the names of persons and of the months make it certain that this tablet is from Dréhem.

TRANSLATION.

Ob. (1) 13 ewes, 1 she-goat,
commissioner, Banaha;
30 she-goats, commissioner Abiga;
23 large kids, commissioner Azagzaqum;
(5) superintendent, Ahuni, sahar.
40 she-goats, commissioner, Irib;
30 large kids, commissioner, Ibshika;
superintendent, Bashagaga, sahar,
the 21st day
(10) of the month Shuessha.
1 sheep, commissioner, Elagnua;
20 large kids, commissioner, Urshika;
superintendent, Bashagaga, sahar.
the 22nd day.

(15) 1 female lamb, 16 sheep,
commissioner, Banaha;
1 female lamb, 16 sheep,
commissioner, Basha-Ishtar;
superintendent, Ahuni, sahar.

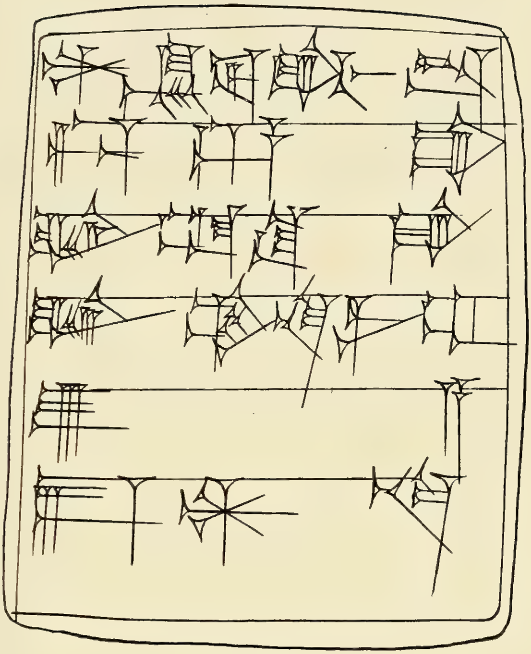
Rev. (1) 22 sheep, commissioner, Elagnua,
superintendent, Bashagaga, sahar,
the 7th day
of the month Ezenmah.
(5) 57 sheep, 8 large kids,
commissioner, Banaha;
23 large kids, commissioner, Abiga;
superintendent, Ahuni, sahar.
(10) 6 large kids, commissioner, Ibshika;
superintendent, Bashagaga, sahar,
the 17th day
of the month Ezenanna.
Delivered by Abbashagga,
(15) Nur-Enzu took (them) in charge.
The year of the installation of the high priest
of Eridu.

Tablet No. 20

This is an acknowledgment of the payment to Ishtarilu of certain amounts of copper and lead, and by Ishtar-ilu to Abu-waqar and Shamash-ilu of amounts of silver and gold. The ratio of silver to copper, lead, and gold is given, but owing to a break in the first line, and line five not being quite clear, the computation is not as certain as one could desire. The broken space in line one of the obverse would suggest that only one wedge is to be supplied. In that case the relative value of silver to copper would be 1 : 93.5. If 2/3 mana 8 shekels of gold was worth 1 mana 7½ shekels of silver, the relative value of silver to gold was 1.66 :1. In Egypt silver was more valuable than gold until the Eighteenth dynasty, when the ratio of silver to gold became 1 2/3 :1 (See BREASTED, *A History of Egypt*, pp. 98, 185, 338). In an article on the relative value of gold, silver and copper (*Revue d' Assyriologie* 1911, pp. 92-93), FR. THUREAU-DANGIN has shown that in Sippar at the time of Hammurapi the ratio of gold to silver was 6 :1. This tablet is undated but the

No. 21.

OBVERSE



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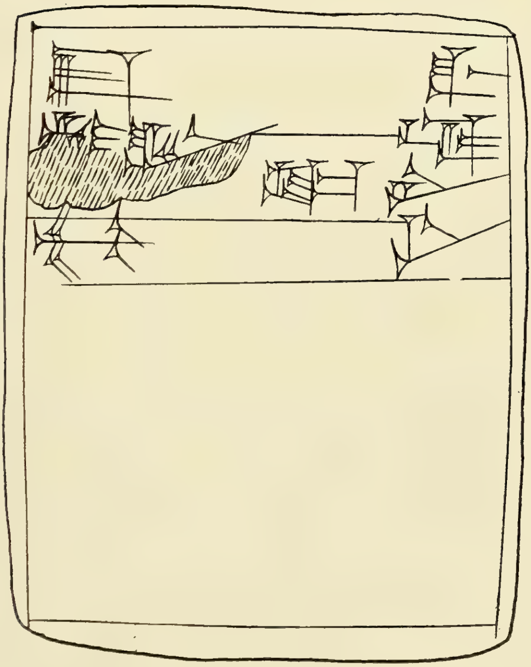


script shows clearly that it comes from the time of the first dynasty of Babylon (2060-1761 B. C.). Unbaked. Size: length 6.6 centimeters, width 4.7 centimeters.

TRANSLATION.

Ob. (1) [(?)] talents of bronze
received
Ishtar-ilu,
1 mana 17 shekels (is) its (value in) silver.
(5) ? mana of lead
1 mana (is) its (value in) silver,
received
Ishtar-ilu.

Rev. (1) 1 1/3 mana 8 shekels of silver,
2/3 (mana) ½ shekel of gold
for 1 mana 7½shekels of silver,
from Ishtar-ilu
(5) received
Abuwaqar
[an]d Shamash-ilu.

Tablet No. 21

Sin-gashid, King of Uruk, ruled from about 2150 to 2110 B. C. Uruk, or Erech, is the second of the four Babylonian cities founded according to Genesis 10.10 by Nimrod. The mound of some six miles in circumference, is situated on the left bank of the Euphrates, and is now known as Warka. Baked. length 8.5, width 6.7 centimeters.

TRANSLATION.

Ob. (1) Sin-gashid,
the mighty hero,
King of Uruk,
King of Amnanu,
(5) who cares for
Eanna[1],

Rev. (1-2) his royal palace
has built.

---

[1] Eanna is the name of the temple of the goddess Ishtar in Uruk.

A Revision of the North American Species
OF THE
Dipterous Genus Diaphorus.

M. C. VAN DUZEE

In separating the genus Diaphorus from Chrysotus I have found no better method than that proposed by Prof. J. M. Aldrich in his paper on the Dolichopodidae of Grenada, Kansas University Science Bulletin, vol. i, p. 85, 1902. To place in Chrysotus all species in which the eyes of the male are approximated below the antennae and in Diaphorus all in which they are approximated above the antennae; where there is no approximation to refer to Chrysotus all in which the male have no large bristles at the tip of the abdomen. Nearly all the species falling in Diaphorus by these rules have the pulvilli of the fore and sometimes those of the middle and hind tarsi enlarged, and also have more or less distinct bristles at the tip of the abdomen; there are exceptions but one of these characters is always present to determine the position of the species. I do not know of any species that could be placed in Chrysotus by this method of separation that have bristles at the tip of the abdomen larger than those on the hind margins of the other segments, and only a few species in which the fore pulvilli are enlarged and then not conspicuously so, the group to which *Chrysotus discolor* Loew, belongs have the pulvilli enlarged as much as any I have seen in that genus. The Diaphorus are usually more slender and the abdomen more cylindrical than those of the Chrysotus. The third and fourth longitudinal veins are nearly straight and parallel beyond the posterior cross vein, except in D. simplex Ald. and D. repandus n.sp. where they are bent. (Fig. 14).

Prof. J. M. Aldrich has called my attention to the separation of the Diaphorus into two genera by Kowarz; the characters given in his table to separate them are "Wings oval, eyes of the male broadly separated on the front, Melanostolus; Wings wedge-shaped, eyes of the male contiguous, Diaphorus." It seems to me very unsatisfactory to attempt to divide our species by the shape of their wings, and the separation of the eyes alone seems insufficient for the establishment of the genera.

The following key is based on males only except in one case, that of D. antennatus n. sp. where the first antennal joint is yellow and there is a yellow band at the base of the second abdominal segment; this female is so distinct from all others in the genus that I have ventured to describe it; all other species described in this paper are founded on the males only, in many cases it would be difficult to separate the females of allied species, and sometimes not easy to decide whether a female belonged to this genus or was a Chrysotus. Where I could find characters that seemed sufficient to be of any value I have given them after describing the male.

The characters used for separating the species are, the form of the third antennal joint, this is always of much importance; the general color is used but is subject to considerable variation, even the yellow on the venter and base of the abdomen varies in some species very much, in D. *lamellatus* Loew some specimens show scarcely a trace of yellow even on the venter while others have the venter and a narrow band on the dorsum of the second segment yellow; the color of the legs is more constant, but sometimes where species have yellow tibiae they become more or less brownish. The color of the pollen on the head and thorax never varies as far as I have observed. The cilia of the tegulae is subject to much variation in those species having pale cilia, mostly depending on the direction from which it is viewed. I think those species that are placed in the key under "Cilia black" never vary, but if a specimen has blackish cilia and cannot be placed under "cilia black" it should be taken through as "cilia pale" before deciding that it is undescribed. The length of the first vein is a good character used in separating some species. The appendages of the hypopygium are used in a few cases but care should be used not to give too much importance to the length and form of the central filiament or penis as it varies greatly, in D. *sodalis* Loew, it is usually invisable but I have seen a specimen where it was very long, the same is true of D. *leucostoma* Loew, and others; in life they probably have the power of extending it at will. The width of the face and front is always important.

Specimens of this genus are not numerous in any collection, they are usually taken one at a time and many of the species are described from a single specimen.

I am indebted to Prof. J. M. Aldrich for the loan of his material, which contained many new species; to Prof. C. W. Johnson, Mr. Nathan Banks, Prof. J. S. Hine, and Mr. H. S. Harbeck for the loan of their material; to Dr. J. C. Bradley for the loan of the material in the Cornell University collection, and to Mr. E. T. Cresson, Jr., for the loan of the material of the American Entomological Society.

Table of Species.

1.	Dorsum of the abdomen more or less yellow at base.	2.
	Abdomen without yellow on the dorsum.	7.
2.	Fore and middle femora entirely yellow.	4.
	Fore and middle femora partly black.	3.
3.	All femora black with the extreme tips yellow.	1, *lamellatus* Loew.
	Fore and middle femora with the basal half black.	2, *basalis n.sp.*
4.	Cilia of the tegulae black, second and third segments of the abdomen yellow, antennae black.	3, *dimidiatus* Ald.
	Cilia of the tegulae pale, at least in certain lights.	5.
5.	Antennae black.	6, *ventralis, n.sp.*
	Antennae yellowish brown, or with the first joint yellow.	6.
6.	Front and thorax with violet reflections, antennae yellowish brown.	5, *satrapa* Wh.
	Front and thorax green, covered with yellowish pollen, first antennal joint yellow.	4, *antennatus, n.sp.*
7.	Femora green, black or brown, the tips may be yellow.	8.
	Femora yellow.	36.
8.	Eyes of the male contiguous.	9.
	Eyes not contiguous.	13.
9.	Color of the dorsum of the thorax opaque black or brown.	10.
	Color of dorsum more or less green.	12.
10.	Halters and tegulae yellow.	7, *contiguous* Ald.
	Halters and tegulae black.	11.

11. Eyes broadly contiguous, tibiae yellow, at most yellowish brown, (Eastern species). 8, *opacus* Loew.
Eyes narrowly contiguous, legs altogether black. (Western species). 9, *adustus n.sp.*

12. Tegulae, their cilia and the halters black, length 2 mm. 10, *gibbosus n.sp.*
Tegulae and halters yellowish, cilia of the tegulae black to pale yellow, length 3.5-4 mm. 12, *spectabilis* Loew.

13. Pulvilli of fore tarsi not or but slightly enlarged. 14.
Pulvilli of fore tarsi distinctly enlarged. 17.

14. Pulvilli not at all enlarged; thorax with a violet vitta. 13, *caerulescens* Loew.
Fore pulvilli slightly enlarged; thorax without violet. 15.

15. Hind metatarsi with a long erect bristle below. 15, *simplex* Ald.
Hind metatarsi without such a bristle. 16.

16. Thorax with a coppery vitta. 14, *vittatus n.sp.*
Thorax without a vitta. 16, *alienus n.sp.*

17. Palpi much enlarged. 18.
Palpi normal. 19.

18. Palpi as long as the face; face not unusually wide; tibiae black. 32, *palpiger* Wh.
Palpi about half as long as the face; face very wide; tibiae yellow. 33, *triangulatus n.sp.*

19. Cilia of the tegulae pale. 20.
Cilia black. 32.

20. Face with yellow pollen. 21.
Face with white pollen. 22.

21. Face with course pollen; third antennal joint large, kidney-shaped. 17, *rauterbergi* Wh.
Face green with thin pollen along the sides; third antennal joint of moderate size. 18, *albiciliata n.sp.*

22. Third antennal joint subquadrate but may have a short point at upper corner. 31.
Third joint rounded or with a point at tip. 23.

23. Third antennal joint large with a rather sharp point, as long as the two basal joints together. (When viewed from the outer side). 24.

Third joint distinctly shorter than the two basal joints or rounded at tip. 28.

24. Hind tibiae yellow. 25.

Hind tibiae and all tarsi black or brown. 27.

25. Thorax with a coppery vitta. 14 *vittatus n.sp.*

Thorax without a vitta. 26.

26. Hind tibiae entirely and hind tarsi partly yellow. 19, *leucostoma* Loew.

Hind tibiae with the tip broadly and hind tarsi entirely black or brown. 20, *leucostoma* Loew. *var. infuscatus n. var.*

27. Point at tip of third antennal joint rather short (Fig. 11). 22, *occidentalis n.sp.*

Point at tip of third joint long. (Fig. 10). 21, *quadratus n.sp.*

28. Third antennal joint about as long as the first, as broad as long with a short but sharp point at center of apex (Fig. 1). 23, *parmatus n.sp.*

Third joint rounded at tip. 29.

29. Third antennal joint as long as the first two (Fig. 2); palpi small. 24, *remulus n.sp.*

Third joint shorter than the first; palpi as large as usual. 30.

30. Third antennal joint short, rather flattened at tip; arista apical; third vein bent. (Figs. 3 and 14). 25, *repandus n.sp.*

Third joint small, slightly pointed at tip; arista subapical (Fig. 4); third vein nearly straight. 26, *usitatus n.sp.*

31. Color blue-green; last section of fourth vein considerably bent. 27, *aldrichi n.sp.*

Color green, inclined to golden; last section of fourth vein nearly straight. .. 28, *similis n.sp.*

32. Outer appendages of the hypopygium are large spatuleate lamellae. 1, *lamellatus* Loew.

Appendages small, not lamellaform. 33.

33 Hypopygium large and conspicuous. 11, *nigrescens* Ald.
Hypopygium normal. 34.

34. Fore coxae with a few minute pale hairs and black bristles. 29, *sodalis* Loew.
Fore coxae with black hairs and bristles. 35.

35. Middle tibiae with two prominent bristles on the front side, one near the base and one at the middle; thorax vittate. 30, *trivittatus n.sp.*
Middle tibiae with only one bristle which is near the base; thorax not vittate. 31, *dubius* Ald.

36. Male with very large, pendant, white palpi. 34, *amoenus* Ald.
Male with the palpi normal. 37.

37. Eyes of the male not contiguous. 38.
Eyes of male contiguous. 42.

38. Front and thorax with little pollen; tip of abdomen of male without stout bristles. 35, *parvulus* Ald.
Front with considerable pollen; tip of abdomen with distinct bristles. 39.

39. Face narrower than the front: thorax with or without a bronze vitta. 36, *variabilis n.sp.*
Face wider than the front. 40.

40. Fore coxae black. 41, *femoratus n.sp.*
Fore coxae yellow. 41.

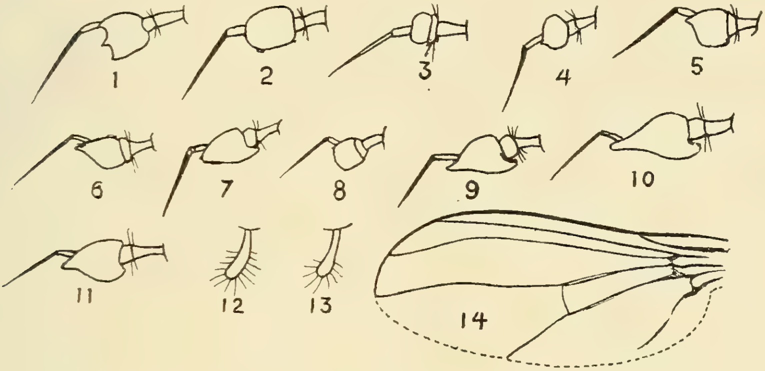
41. Venter yellow. 6, *ventralis n.sp.*
Venter not yellow. 37, *subsejunctus* Loew.

42. Middle and hind coxae infuscated for half their length; antennae black. 40, *deceptivus* Ald.
Fore and hind coxae altogether yellow, middle coxae darkened at base; antennae partly yellowish. 43.

43. Thorax with but little pollen; abdomen without stout bristles at tip. 38, *flavipes* Ald.
Thorax with thick yellowish pollen; bristles at tip of abdomen short but distinct. 39, *mundus* Loew.

Explanation of Figures.

1-11 antennae of Diaphorus. 1 D. parmatus n. sp. 2 remulus n.sp.; 3 repandus n.sp.; 4 usitatus n.sp.; 5 aldrichi n.sp.; 6 similis n.sp.; 7 triangulatus n.sp.; 8 alienus n.sp.; 9 leucostoma Loew; 10 quadratus n.sp.; 11 occidentalis n.sp.; 12 lamella of the hypopygium of D. lamellatus Loew; 13 lamella of the hypopygium of D. basalis n.sp.; 14 Wing of D. repandus n.sp.



1 Diaphorus lamllatus Loew.

Diaphorus Lamellatus Loew, Mon. N. A. Dipt, ii, 165.

Male: Length 2.6-4 mm. Eyes narrowly separated by the front; antennae small, black; arista subapical. Thorax and abdomen metallic green, the former with brownish yellow dust; bristles at the tip of the abdomen remarkably strong; outer apendages of the hypopygium elongated, spatulate lamellae (Fig. 12). Coxae and feet black, basal half of the four anterior tibiae yellowish; pulvilli of fore tarsi much elongated. Halters and tegulae yellow, the latter with black cilia. Wings grayish hyaline; the first vein reaching about two-fifths the distance to the tip of the second vein.

The venter is usually yellowish at the base of the abdomen, and in some specimens the yellowish color forms a narrow band on the dorsum at the base of the second segment.

Middle States Loew; I have seen specimens from N. Y., Pa. and Va.

2 Diaphorus basalis n. sp.

Male: Length 3.75 mm. Face subquadrate and rather deeply depressed, black with thin white pollen; proboscis black; palpi yellowish; eyes touching or nearly so on the center of the front, leaving a small triangle above the antennae; antennae small, black, third joint very small, rounded with a dorsal arista; lateral and inferior orbital cilia white. Thorax metallic green dulled with gray pollen; pleurae greenish black with white pollen. Abdomen dark metallic bronze with the second and part of the third segment yellow, still a narrow hind margin of the second dark; hairs of the abdomen black, tip with six or seven strong bristles; hypopygium conspicuous with long spatulate lamellae (Fig. 13), which are brown with the tip more blackish and fringed with long brown hairs. Coxae and femora black; the tips of the fore coxae, their trochanters, and the apical half of the fore and middle femora yellow; all tibiae and fore and middle tarsi yellow, these tarsi brownish towards the tips; extreme tips of hind tibiae and their tarsi brown; all femora ciliate below with long brown hairs, those on the middle pair shorter and more bristle-like, hind femora also with rather long hairs above; fore tibiae with long hairs; middle tibiae with a bristle near the knee on the front side and two or three small ones below; hind tibiae with one bristle near the base on the outer-upper edge and a row of bristle-like hairs and several larger bristles on the upper-inner edge; fore tarsi about one and a half times as long as their tibiae and with their pulvilli much enlarged and lengthened, being fully as long as the fifth joint, there are a few long hairs at the tip of the fifth joint; pulvilli of the middle and hind tarsi but little enlarged; middle tarsi a little longer, and the hind tarsi scarcely as long as their tibiae. Halters and tegulae yellow, the latter with black cilia. Wings tinged with brown; first vein reaching about one half the distance to the tip of the second vein.

Described from one male taken by Mr. Nathan Banks, at Glencarlyn, Va. Type in Mr. Banks' collection.

This species is closely related to D. *oculatus* Fall. from Europe, the third joint of the antenna is the same, as is the general color, but it differs in having no bristles on the fore tibiae and in the arrangement of the bristles of the other legs. The *lamellae* of the hypopygium are much like those of D. *lamellatus* but much more slender.

3 Diaphorus dimidiatus Ald.

Diaphorus dimidiatus Ald., Trans. Ent. Soc. London, 1896, pt. iii, p. 322.

Male: Length 2 mm. Eyes separated by the front; antennae black, the third joint very short; arista dorsal. Thorax light green, bluish, white dusted. Abdomen with second and third segments yellow; apical segments green, a little coppery; four apical bristles large. Fore coxae black with a row of three long black bristles; middle coxae black with yellow tips; hind coxae yellowish brown; femora, tibiae and tarsi yellow; tarsi infuscated at tips; fore pulvilli as long as the third joint of fore tarsi, middle pulvilli nearly as large as those of the fore tarsi. Halters and tegulae yellow, the latter with black cilia. Wings subhyaline.

W. I.

4 Diaphorus antennatus n. sp.

Female: Length 4 mm. Face wide, thickly covered with silvery white pollen which is more abundant below the suture; papli yellowish with white pollen and coarse black hairs; proboscis black; antennae with the first joint yellow, second and third black, third joint short, rounded, flattened in outline at the tip; arista apical, black, as long as the height of the eye; front green covered with yellowish gray pollen. Thorax green, dorsum thickly covered with yellowish pollen; pleurae with white pollen; scutellum blue-green. Abdomen green, in one specimen with golden reflections, in the other blue-green; venter, sides of the second and third, and a band at the base of the second segment above yellow; the bristles on the hind margins of the segments large and conspicuous. Legs and fore coxae yellow; tarsi becoming dark brown from the tip of the second joint; middle and hind coxae black with yellow tips and a large bristle on the outer surface; fore coxae with thin silvery pollen and minute pale hairs on the front surface and with black bristles at tip; middle and hind trochanters with a black bristle above; fore tibiae with a prominent bristle near the base on the upper side; middle tibiae with a long stout bristle near the base on the front side, and also several minute bristles; hind tibiae with two bristles at basal fourth, two beyond the middle above and several smaller ones. Tegulae and halters pale yellow, the cilia of the former yellow but appearing blackish in certain lights. Wings grayish hyaline, veins brown, yellow at the root of the wing; first vein reaching only about one-third of the distance to the tip of the second vein.

Described from two females from Vera Cruz and Cordoba, Mex. (Crawford), in the J. M. Aldrich collection and presented to him by Prof. Charles Fuller Baker. Type in the collection of J. M. Aldrich.

Easily distinguished by the yellow band at the base of the second segment of the abdomen, and the first antennal joint and the legs being yellow.

5 Diaphorus satrapa Wheeler.

Diaphorus satrapa Wheeler, Psyche, June, 1890, p. 359.

Male: Length 2 mm. Antennae yellowish brown with the third joint pointed; front bronze black with violet reflections. Dorsum of the thorax blackish bronze with a shining violet patch bordered on each side by a broad, poorly defined, cupreous band. Abdomen with the first segment bronze-green, second and third mostly yellow, posterior segments blackish-bronze. Coxae and feet pale yellow; apical half of hind femora brown on the upper surface; tibiae brownish. Halters and tegulae yellowish, cilia of the latter white.

Saline Co., Nebr.

6 Diaphorus ventralis n. sp.

Male: Length 3.5 mm. Face a little longer than wide, covered with white pollen; palpi small, whitish; front narrow, not much more than half the width of the face, green, in certain lights completely covered with gray pollen; antennae small, black, third joint very small, rounded; arista dorsal; orbital cilia white except above. Dorsum of the thorax light green with considerable yellowish pollen, which is thickest on the front and sides; pleurae with gray pollen. Abdomen coppery or bronze colored, more green at tip; venter and more or less of the sides of the second and third segments yellow; venter with a few long hairs on the hind margins of the segments; bristles at the tip of the abdomen of moderate size; hypopygium small, without visible appendages. Fore coxae yellow with black bristles at tip; middle and hind coxae black; legs yellow, tarsi only slightly darker towards the tips; middle tibiae with the usual bristle near the base rather large; fore and middle femora with a few bristle-like hairs near the tip on the lower outer edge; pulvilli of the fore tarsi distinctly enlarged. Tegulae and halters yellow, the cilia of the former appears yellow in most lights, but in a certain direction it appears nearly black. Wings hyaline; first vein scarcely reaching one third of the distance to the tip of the second vein.

Two females from the same location seem to belong here; they agree with the males in the color of the legs, cilia of the tegulae, face and front, the two latter being of about equal width; the thorax is more blue-green and the abdomen pure green, the venter being yellow but this color does not extend up on the sides as in the male. Length 3 mm.

Described from two males and two females labeled (Belize; Johnson), in the collection of Prof. J. M. Aldrich and presented to him by Charles Fuller Baker. Type in the collection of J. M. Aldrich.

Specimens of this species will be likely to be found with the yellow of the venter extending more or less onto the dorsum as it does sometimes in D. *lamellatus* Loew.

7 Diaphorus contiguus Ald.

Diaphorus contiguus Ald. Trans. Ent. Soc. London, 1896, pt. iii, p. 323.

Male: Length 2 mm. Eyes contiguous; antennae very short; arista subapical; cilia of the inferior orbits blackish; dorsum of the thorax and abdomen black, opaque, the former with pale brown dust; bristles at the tip of the abdomen large. Coxae and femora black, tips of the femora, tibiae and base of tarsi yellow; fore pulvilli large. Halters and tegulae yellow, the latter with black cilia.

St. Vincent, W. I.; Grenada.

8 Diaphorus opacus Loew.

Diaphorus opacus Loew, Neue Beit., viii, p. 56; Mon. N. A. Dipt., pt. ii, p. 160.

Male: Length 2.5-3 mm. Eyes contiguous; antennae black, third joint small, rounded at tip; arista subapical, or perhaps better described as dorsal. Thorax black, dorsum covered with brown pollen, opaque. Abdomen shining, black, bristles at tip large. Coxae and femora black; tibiae yellow, sometimes yellowish brown; tarsi yellow at base, brown at tip; fore pulvilli but little enlarged. Tegulae, their cilia and the halters black. Wings tinged with brown; first vein reaching about two-fifths of the distance to the tip of the second vein, (Loew states that the first vein reaches nearly to the middle of the front margin, but in all the specimens I have seen which answer his description of opacus it does not reach so far). I have seen specimens from Vt., N. Y., Pa., and Toronto, Ont.

9 Diaphorus adustus n. sp.

Male: Length 2.5 mm. Altogether black except that the thorax has a very slight greenish tint, and the knees are very narrowly yellowish, body and legs somewhat shining; face and thorax with brown pollen; pleurae with gray pollen; eyes narrowly contiguous, or scarcely touching on the front; antennae black, third joint very small; arista dorsal; bristles at the tip of the abdomen strong. Middle tibiae with the bristle near the knee rather small; hind tibiae with four or five small bristles on the upper surface; pulvilli of fore tarsi enlarged, yellowish brown. Wings tinted with brownish; first vein reaching about two-fifths of the distance to the tip of the second vein; costa scarcely enlarged beyond the tip of the first vein.

Described from three males from Idaho and Nev., the latter taken July 12th. Type in J. M. Aldrich collection.

The relation of this species to *opacus* Loew is very close, but it is separated from that species by the altogether black legs, and the more shining thorax with its slight greenish tint, in opacus the tibiae are yellow or brownish yellow, if the tibiae are brown in adustus they are of the same shade as the femora and are not yellowish brown; from D. *gibbosus* it is more widely separated by the longer first vein, more thickened costa, and more arched thorax of *gibbosus n.sp.*

10 Diaphorus gibbosus n. sp.

Male: Length 3 mm. Face, palpi and proboscis black; face with gray pollen; antennae small, black, third joint very small; arista dorsal; eyes contiguous, leaving only a very small black triangle above the antennae; occalii not so prominent as in most species that have the eyes contiguous; cilia of the interior orbit dark brown. Dorsum of the thorax prominently elevated and including the scutellum dark green, somewhat shining; in front and along the lateral sides more blackish and opaque being covered with thick brown pollen, which in most specimens forms two indistinct vittae on the front of the dorsum; pleurae black with dark brown pollen. Abdomen dark brown or black, almost opaque still with slight greenish reflections, and with quite abundant, rather long brown hairs; bristles at the tip of the abdomen not very long but prominent; appendages of the hypopygium very small, black. Halters black; tegulae brown with narrow black border and black cilia. Coxae and femora black; tibiae and first joint of tarsi yellowish brown, tarsi from the tip of the first joint darker; pulvilli of the fore tarsi moderately enlarged, those of the middle tarsi less so, and those of the hind tarsi scarcely enlarged; fore femora with long hairs on the lower outer edge, these hairs as long as the thickness of the femora; middle and hind femora with hairs similarly placed but the hairs are much shorter on the basal half; all tibiae with long hair but without bristles except a small slender one on the middle and hind pair near the knee and several very minute ones on the hind pair. Wings strongly tinged with brownish; first vein reaches about half way to the tip of the second vein; veins black; costa somewhat enlarged from just before the tip of the first vein to the tip of the second vein or beyond.

Described from twelve males; two taken at Little Valley, N. Y., June 10th; three from Colden, N. Y., May 31st; one from Ft. Erie, Ont., June 20th, this one has the thorax more purple than green; one from Castle Rock, Pa., May 21st, and one marked "June," sent by E. T. Cresson, Jr.; two from Auburndale, Mass., July 12th and June 4th, one from Manchester, Vt., June 8th, and one from Johnsbury, Vt., June 27th, sent by C. W. Johnson; one from Monmouth, Me., June 27th (C. A. Frost). Type in the author's collection.

Specimens from St. Vincent sent me by Prof. J. M. Aldrich seem to belong here, although the costa is not thickened and they are somewhat smaller.

11 Diaphorus nigrescens Ald.

Diaphorus nigrescens Aldrich, Biologia Diptera, i, p. 346.

Male: Length 3.1 mm. Eyes separated by the front but not widely so; antennae small, black; arista apical; thorax opaque black, a little shining behind; abdomen blackish-green, shining, apical bristles distinct; hypopygium large; legs opaque black, all the knees yellow; pulvilli white, moderately enlarged. Wings uniformally infuscated, not very dark. Halters yellow; cilia of the tegulae black, that of the inferior orbits yellowish.

Mexico.

12 Diaphorus spectabilis Loew.

Diaphorus spectabilis Loew, Neue Beitr., viii, p. 57; Mon. N. A. Diptera, ii, p. 162.

D. *approximatus* Aldrich, Trans. Ent. Soc. of London, 1896, pt. iii, p. 321.

Male: Length 3.5-4.25 mm. Eyes contiguous; antennae small, black; arista almost apical; thorax and abdomen bronze green, the former with yellowish brown dust, but quite shining; bristles at the tip of the abdomen rather striking. Coxae and femora black; tibiae brownish yellow; fore pulvilli very much enlarged. Halters yellow with the tips of their knobs sometimes infuscated; tegulae yellow with blackish cilia which has a yellowish reflection in some lights. Wings tinged with gray.

Prof. Aldrich states that the eyes are narrowly separated in some specimens. He described this form under the name of D. *approximatus*. I have not seen any, where the eyes did not touch on the front.

I have seen specimens from Mo., Ill., Tenn., N. J., D. C., Va., N. C., Ga., La. Prof. Aldrich reports it from W. I. and Mex.

13 Diaphorus caerulescens Loew.

Diaphorus caerulescens Loew, Wien. Ent. Monatsch., i, p. 39; Neue Beitr. viii, p. 60; Mon. N. A. Diptera, ii, p. 170 (all *Lyroneurus*).

Male: Length 3-4 mm. Eyes widely separated by the front; antennae small, black. Thorax pale green with the hind part and a central line blue or violet and with rather thick brownish dust. Abdomen metallic green, blue or violet from the middle of the second segment, tip with four strong bristles. Coxae black with a more or less greenish tint, femora green; tips of femora and all tibiae brownish yellow; pulvilli of fore tarsi not enlarged; tegulae pale yellow with dark brown cilia. Wings grayish hyaline.

Mex.

14 Diaphorus vittatas n. sp.

Male: Length 2 mm. Face wide and short, covered with silvery white pollen, but black in certain lights; front nearly as wide as the face, bright green with very little pollen; antennae black, first joint long and slender, third joint large, pointed with the arista inserted near the tip of this point; palpi rather large, white. Thorax and scutellum bright green with slight golden reflections and almost without pollen, a not very sharply defined, coppery vitta extends from the front of the thorax to the scutellum; pleurae and coxae black, without much pollen, the former with greenish reflections. Abdomen metallic coppery, more golden on the sides; bristles at the tip very short; hypopygium small, its appendages small, black. Femora shining green; trochanters and tibiae sordid yellow; fore and middle tarsi becoming brown from the tip of the first joint; tip of hind tibiae and the hind tarsi brown; the row of hairs on the lower outer edge of the fore femora long; the lateral bristle at the base of the middle tibiae small; pulvilli of fore and middle tarsi a little enlarged. Tegulae, their cilia and the halters yellow. Wings grayish hyaline; veins black; first vein reaches nearly half the distance to the tip of the second vein.

Described from one male taken at Falls Church, Va., by Mr. Nathan Banks in April. Type in Mr. Banks' collection.

This is one of the species that are difficult to place, but the bristles at the tip of the abdomen although they are small and the enlargment of the pulvilli seem to place it in this genus.

The form of the antennae and general color would place it near D. *leucostoma* Loew but it differs from that species, in having a central vitta on the thorax.

15 Diaphorus simplex Ald.

Lyroneurus simplex Aldrich, Trans. Ent. Soc. of London, 1896, pt. iii, p. 333.

Male: Length 3.5-5.5 mm. Eyes widely separated by the front; antennae small, black, third joint crescent-shaped with long, slender, subapical arista. Thorax and abdomen green with considerable brown dust; acrostichal bristles in a single row; bristles at the tip of the abdomen rather long. Tegulae, their cilia, and the halters yellow. Fore coxae green at base becoming yellow at tip; all femora dark green; trochanters, tips of femora, tibiae and base of front and middle tarsi yellow; pulvilli of fore tarsi a little enlarged. Wings yellow at apex in front of the third vein.

W. I., Mex.

16 Diaphorus alienus n. sp.

Male: Length 1.7 mm. Face broad with silvery pollen, but appearing black in certain lights; palpi yellowish, of moderate size; front broad with whitish pollen, which almost conceals the green ground color; antennae black, third joint rather large, somewhat subquadrate, nearly as long as wide; arista inserted just above the upper corner (Fig. 8). Thorax bright green; pleurae more blackish with white pollen. Abdomen green with coppery reflections and without bristles at tip; hypopygium large, partly disengaged, with a curved central filiment, black and somewhat shining. Coxae black, the fore pair with yellow tips and with white hairs on the front surface; trochanters yellowish; femora greenish black; tips of femora and tibiae yellow; tips of hind tibiae and the tarsi brownish; pulvilli of front tarsi but slightly enlarged. Tegulae, their cilia and the halters pale yellow. Wings hyaline; first vein reaching a little more than one-third of the distance to the tip of the second vein.

Described from one male from Hood River, Ore. (J. M. Aldrich).

This species is distinguished by its small size, the large third antennal joint, and the partly disengaged hypopygium. Type in the J. M. Aldrich collection.

This might be placed in *Chrysotus* but seems to fit into this genus better, as the pulvilli of the fore tarsi are somewhat enlarged, the form is rather slender, and the third antennal joint is formed somewhat the same as that of several other species of this genus.

17 Diaphorus rauterbergi Wheeler.

Diaphorus rauterbergi Wheeler, Psyche, June, 1890, p. 360.

Male: Length 3 mm. Face with course yellow pollen; eyes widely separated; antennae black, third joint large, kidney-shaped; arista apical. Thorax and abdomen metalic green with course yellow pollen which is very thick on the thorax. Halters and tegulae yellow, the latter with yellow cilia. Coxae black; femora green with broadly yellow tips; tibiae and tarsi yellow, the latter with enlarged pulvilli on all feet. Wings grayish hyaline.

Saline Co., Nebr.

18 Diaphorus albiciliatus n. sp.

Male: Length 2.1 mm. Face narrower than the front, a little narrowed in the middle, dark green with thin yellow pollen which is more visible when viewed from the side; palpi small yellowish; antennae black, third joint of moderate size, rounded at tip, with rather long pubescens; arista subapical; front dark green with scarcely a trace of yellow pollen. Thorax and scutellum bright green with slight golden reflections and a central coppery vitta, (this vitta may not be found in all specimens, although sharply defined in the type); thorax with very thin gray pollen; pleurae and coxae blackish with gray pollen and green reflections; there is a small white bristle above the fore coxae. Abdomen darker green than the thorax, somewhat coppery towards the tip; hypopygium small with concealed appendages; bristles at the tip of the abdomen very small. Fore coxae green with white hairs on the front surface and with the extreme tips and the trochanters yellow; femora green; tips of the femora, tibiae and tarsi yellow, the latter slightly brownish towards their tips; pulvilli of all tarsi distinctly enlarged; fore femora with the usual row of hairs on the lower hind edge; middle and hind femora with a few bristle-like hairs near the tip. Halters yellow; tegulae and their cilia white. Wings grayish hyaline, slightly tinged with brown along the veins; first vein reaching about one third the distance to the tip of the second vein.

Female: Four females taken with the male described above have the face black with white pollen; front with thick gray pollen. Thorax dull green with thick gray pollen and a trace of the coppery vitta. Abdomen dark green with gray pollen; femora almost black. Tegulae and their cilia white; wings hyaline slightly tinged with grayish; third vein reaching more than one-third of the distance to the tip of the second; costa rather stout beyond the tip of the first vein.

Described from one male and four females taken at Gualan, Guatemala, Feb. 15th. Type in the collection of Prof. J. S. Hine.

The following combination of characters serve to separate this species. Tegulae and their cilia pale, antennae of moderate size with the third joint rounded at tip, face green with yellow pollen, first vein one-third as long as second.

19 Diaphorus leucostomos Loew.

Diaphorus leucostoma Loew, Neue Beitr., viii, p. 58; N. A. Diptera, ii, p. 166.

Male: Length 2.5-3 mm. Eyes widely separated by the front; antennae black, third joint large and with a rather long point (Fig. 9); arista inserted before the tip of this point. Thorax and abdomen bright green, the former with thin grayish dust; bristles at the tip of the abdomen rather long. Coxae black; femora green; tibiae, tips of femora and tarsi yellow, tarsi infuscated towards the tips; pulvilli of all tarsi enlarged. Tegulae, their cilia and the halters yellow. Wings hyaline slightly tinged with gray.

I have seen specimens from Canada, N. Y., N. J., Md., D. C., Ga., La., Ohio, Mich., Mo., and Guatemala. Prof. Johnson reports it from Fla.

20 Diaphorus leucostoma var. infuscatus n. var.

Male: Very much like D. *leucostoma*. Length 3.3 mm. Hind tibiae have their tips blackish, hind tarsi entirely blackish; the third vein is bent backward slightly more than in *leucostoma* and the second vein extends somewhat further towards the apex of the wing.

Two males Washington, D. C. and N. J.

The three species belonging to the *leucostoma* group, which have the eyes widely separated by the front, the cilia of the tegulae pale, the third joint of the antennae as long as the two basal joints and with a pointed tip are separated as follows; *leucostoma* has the face distinctly longer than wide, the hind tibiae yellow, the fore femora with rather short hairs on the lower side, and the thorax green with more or less coppery or golden reflections. The other two have the thorax bluish, the face nearly or quite as wide as long, and the hind tibiae brownish or blackish. In *quadratus* the hind femora have rather long hairs on top and only short hairs below, the face almost square, and the third joint of the antennae with a rather sharp point; while in occidentalis the face is slightly longer than wide, there are long bristly hairs on the lower outer edge of all femora, and the hairs on the top of the hind femora are no longer than on the sides.

21 Diaphorus quadratus n. sp.

Male: Length 3 mm. Face very wide, nearly square, so thickly covered with silvery white pollen as to conceal the ground color, rather flat with a depressed line in the center, deepest near the antennae and not reaching the oral margin; palpi small, brownish with pale edges and white pollen; front as wide as the face with nearly parallel sides, bluish green, with white pollen which is thickest near the antennae; antennae black, third joint large with a long point (Fig. 10), arista inserted before the tip of this point; lower and lateral orbital cilia white and rather long. Thorax blue-green, dulled with gray pollen; pleurae green with blue reflections in front of the middle coxae. Scutellum and abdomen bright green, shining, abdomen depressed, the hairs on the sides and venter yellowish, stiff as are also the black hairs on the dorsum, the bristles on the posterior margins of the segments long, those at the tip a little longer and stouter; hypopygium small and its appendages concealed. Coxae black, the fore pair somewhat greenish, with yellow tips and trochanters and long white hairs on the front surface; middle and hind pairs with white pollen; femorra bright green with the extreme tips yellow; fore and middle pairs with long, black, bristle-like hairs on the lower-front edge; hind pair with rather long hairs above and shorter hairs below; fore and middle tibiae yellow; hind tibiae brownish black; fore and middle tibiae without bristles except the usual one near the base of the middle ones; hind tibiae with a number of bristles on the top, five or six of which are longer than the rest, and one bristle near the base on the outer side; fore and middle tarsi brown and about equal to their tibiae in length; hind tarsi black and about three-fourths as long as their tibiae; pulvilli of the fore tarsi only a little enlarged, those of the middle and hind tarsi not at all enlarged. Halters and the tegulae and their cilia pale yellow. Wings broad; hyaline, scarcely tinged with gray; veins black; first vein reaches scarcely one-third of the distance to the tip of the second vein.

Described from a single male which I took at Fort Erie, Ont., May 30th, 1911. Type in author's collection.

22 Diaphorus occidentalis n. sp.

Male: Length 3-3.2 mm. Face wide, a little longer than wide with silvery white pollen; palpi brown when viewed from the side, white when seen from the front; antennae black, third joint large with a short point, about as broad at the widest part as long, nearly as long as the two basal joints together (Fig. 11); front bluish green with white pollen which is thickest below, about as wide as the face; lateral and inferior orbital cilia white, the white beard below the mouth long and bushy. Thorax blue-green on the dorsum with white pollen; pleurae more blackish and covered with gray pollen. Abdomen green with long white hairs on the sides at base and on the venter; bristles at the tip rather long; hypopygium small, appendages concealed except the central filiment which in the described specimens is rather long and directed downward. Coxae black; the fore pair greenish with white pollen and long white hairs on the front surface, their tips and trochanters yellow; femora metallic green with yellow tips and long dark hairs on the lower-front edges; fore and middle tibiae and the base of their tarsi yellow, the tarsi becoming brownish towards their tips; hind tibiae and tarsi yellowish brown; bristle at the base of the middle tibiae rather slender; bristles of hind tibiae long; pulvilli of all tarsi distinctly, though moderately enlarged. Tegulae, their cilia and the halters pale yellow. Wings hyaline, scarcely tinged with gray; first vein not reaching quite half the distance to the tip of the second.

Described from three males from Hood River, Ore. Type in the collection of J. M. Aldrich.

A female from the same location may belong with these males but the thorax is green and more shining, and the middle tibiae have two large bristles on the fore surface; this last character makes it doubtful whether they belong to the same species.

This species is very much like *quadratus* but the face is hardly as long as wide, the hind femora have long bristle-like hairs below which are not found in quadratus, while that species has noticeably long hairs above and this species has not; this species has a shorter point at tip of the third antennal joint, which is placed nearer the top of the joint than in *quadratus*.

23 Diaphorus parmatus n. sp.

Male: Length 3 mm. Face very wide, a little longer than wide with silvery pollen, but appearing blackish when viewed from in front; palpi brownish when seen from the side, more whitish when viewed from in front; antennae black, third joint nearly as long as the first with a short but sharp point at the center of the tip (Fig. 1); (Arista missing in the described specimen, in the drawing it is placed as it is supposed to belong, the specimen showing where it has been broken off); front blue with thick white pollen which conceals the ground color in certain lights; lateral and inferior orbital cilia white, the long hairs on the lower part of the orbit white and bushy. Thorax metallic green, the hind part and the scutellum more bluish; dorsum dulled with white pollen, pleurae covered with thick white pollen. Abdomen green with long white hairs on the sides at base and on the venter, and with six stout bristles at tip; hypopygium completely concealed. Coxae black; fore pair greenish and covered with white pollen, with long, coarse, white hairs on the front surface; femora metallic green with yellow tips; fore and middle tibiae yellow; hind tibiae and tarsi brown; fore and middle tarsi brownish almost from the base and with their pulvilli considerably enlarged, those of the fore tarsi largest; all femora with bristly hairs on the lower front edge; middle tibiae with the usual bristle near the base; hind tibiae with long brownish hairs and rather long bristles; hind tarsi also hairy and with the first joint nearly as long as the two following joints. Halters and tegulae pale yellow, the cilia of the latter white, however in certain lights against a white background they may appear brown. Wings hyaline; first vein reaches about two-fifths of the distance to the tip of the second. (The costa in the described specimen is bent at the tip of the first vein in both wings but this may be accidental).

Described from one male labeled "Calif.' Coquillette." Type in the collection of Prof. J. M. Aldrich.

Separated from related species by the shield-shaped third antennal joint.

24 Diaphorus remulus n. sp.

Male: Length 2.7 mm. Face wide with silvery pollen but appearing black when viewed from in front; palpi rather small with the extreme base brown; front green with white pollen on the lower part, a litttle wider than the face; antennae black, third joint a little longer than the first, widest near the base, broadly rounded at tip (Fig. 2); arista subapical; lateral orbital cilia whitish. Dorsum of the thorax green, dulled with gray pollen; pleurae and scutellum more blue-green, the former with white pollen. Abdomen green with whitish pollen which leaves a darker central line when viewed from behind; hairs of the abdomen rather long, black above, white below; bristles at the tip rather long; hypopygium small with its appendages scarcely visible. Coxae black, the fore pair greenish with white pollen and long white hair on the front surface, their tips and trochanters pale yellow; femora metallic green with yellow tips and with a row of delicate hairs on the lower front edge, those on the hind pair stouter; tibiae and fore and middle metatarsi yellow; fore and middle tarsi brown from the tip of the first joint; tips of hind tibiae and hind tarsi brownish; the usual bristle near the knee on the middle tibiae; bristles of the hind tibiae large. Halters and tegulae pale yellow, the cilia of the latter white but in certain lights almost black. Wings hyaline, scarcely tinged with gray; first vein reaching two-thirds the distance to the tip of the second.

Female: Differs from the male in having the palpi larger; the face with a transverse suture below the middle, third joint of the antennae small and the color of the pleurae and scutellum green, without a trace of blue.

Described from one male from Brookings, S. D. Type in the collection of Prof. J. M. Aldrich.

Separated from related species by the peculiar paddle-shaped antennae.

25 Diaphorus repandus n. sp.

Male: Length 3.5 mm. Face wide, covered with white pollen, the green ground color showing through in most lights; palpi yellowish brown with white pollen which gives them the appearance of being white towards their edges; front bluish green with thin yellowish pollen; antennae black, the third joint very short, slightly flattened at tip (Fig. 3); arista apical; cilia of the lateral and inferior orbit white; hairs on the lower part of the head rather long. Dorsum of the thorax green with yellowish pollen; pleurae and scutellum more blue-green, the former with white pollen. Abdomen green with slight coppery reflections and with considerable white pollen; when viewed in the right light it shows a dark central line; bristles at the tip of the abdomen small; hypopygium small, its appendages scarcely visible. Coxae black with their tips and trochanters yellow, covered with white pollen; fore coxae with short white hairs on the front surface and black bristles at tip; femora dark green, fore and middle pairs broadly and hind pair narrowly yellow at tip; tibiae and base of fore and middle tarsi yellow; fore and middle tarsi brown from the tip of the first joint and the hind tarsi brown from the base; pulvilli of fore tarsi only slightly enlarged; fore and middle femora with a few bristle-like hairs at tip; fore and middle tibiae with a bristle near the knee on the front side; hind tibiae with a bristle at first and another at second, third on the outside, and three smaller ones on the upper side; fore and middle tarsi longer than their tibiae, the first joint being about as long as the three following together; hind tarsi much shorter than their tibiae. Tegulae, their cilia and the halters pale yellow. Wings grayish hyaline; the first vein reaching about one-third of the distance to the tip of the second vein; third vein bent backwards towards the tip somewhat as in D. *simplex* Ald. (Fig. 14); veins brown, yellow at the root of the wing.

Described from two males from California, one labeled "Claremont, Cal., Baker;" the other "Three Rivers, Calif., Clbrtson," both from the Aldrich collection, and presented to him by Prof. C. Fuller Baker. Type in the collection of Prof. J. M. Aldrich.

26 Diaphorus usitatus n. sp.

Male: Length 2.1 mm. Face wide with the sides parallel, covered with silvery pollen; palpi rather large, as long as the proboscis, yellowish white, brownish at base; front metallic green with very thin white pollen, a little wider than the face; antennae black, third joint a little shorter than the first, slightly pointed at tip (Fig. 4); arista inserted just above this point; cilia of the lateral and inferior orbits white; the hairs on the lower part of the orbits rather long and abundant. Thorax and scutellum metallic green with golden reflections and considerable white pollen on the dorsum; pleurae dulled with white pollen. Abdomen metallic green with a little white pollen along the sides and rather long white hairs on the venter and lower part of the sides, bristles at tip very short but stout as if broken off; hypopygium small, concealed, with a long stout, dark brown filament inserted at base below and directed forward, nearly as long as the diameter of the hypopygium (this may not be found in all specimens.) Coxae black the fore pair slightly greenish, tipped with yellow, with white hairs on the front surface; middle pair with a few white hairs; hind pair with the usual black bristle on the outside; fore trochanters yellow; femora metallic green with yellow tips; tibiae and base of tarsi yellow still the tibiae slightly brownish at tip; hind tarsi brown almost from the base; fore and middle tarsi becoming brownish from the tip of the first joint; middle tibiae with the usual bristle near the knee rather large; bristles of the hind tibiae small; hind femora with a few bristle-like hairs close to the tip on the outside; pulvilli of the fore tarsi a little enlarged; fore and middle tarsi a little longer than their tibiae, the first joint about as long as the three following; hind tarsi shorter than their tibiae, the first joint longer than the second. Tegulae, their cilia and the halters pale yellowish white. Wings hyaline; veins brownish, yellow at the root of the wing; first vein reaching two-fifths of the distance to the tip of the second.

Described from one male from Hood River, Ore.; and one male from Lewiston, Idaho. Type in the collection of Prof. J. M. Aldrich.

The specimen from Idaho has the tips of the hind tibiae and the hind tarsi brown, and the hair on the venter somewhat shorter.

27 Diaphorus aldrichi, n. sp.

Male: Length 2.75-3 mm. Face broad, a little longer than wide, when viewed from in front black, from the side or above silvery white; palpi small, black with stiff black hairs; antennae black, third joint rather large, subquadrate, scarcely as long as broad (Fig. 5); arista dorsal; front and occiput blue-green, the pollen of the face extending somewhat above the antennae; cilia of the inferior orbits white. Thorax and abdomen bright blue-green, the former with thin whitish pollen around the edges of the dorsum; pleurae more thickly white pollenose; abdomen with rather long white hair on the lower lateral sides and on the venter; hypopygium concealed; bristles at tip rather long. Coxae and femora blue-green; femora with a row of stiff hairs on the lower front edge; fore coxae with long white hairs on the front surface; extreme tips of fore and middle femora and their tibiae yellow; hind tibiae and all the tarsi blackish; middle tibiae with a bristle on the front side near the knee; hind tibiae with a row of bristles above. Tegulae, their cilia and the halters yellow. Wings hyaline; second section of the costa one and a half times as long as the first; costa scarcely thickened beyond the tip of the first vein; third vein distinctly arched so as to run closer to the second vein than in most species; the fourth vein also bent beyond the cross vein but nearly parallel with the third towards the tip.

Described from two males taken at Boise, Idaho. Type in the collection of J. M. Aldrich.

28 Diaphorus similis n. sp.

Male: Length 3 mm. Face and the rather large triangular palpi silvery white; antennae black, third joint subquadrate, with a short point at the upper corner, about as long as broad (Fig. 6); arista inserted just above the point on the upper edge; front green with the pollen of the face extending up onto the lower part; latral and inferior orbital cilia white. Dorsum of the thorax bright metallic green with a very little white pollen which forms a spot on each side in the sutural depression; pleurae more blackish, covered with white pollen. Abdomen metallic green with coppery reflections, hairs on the dorsum short, black; venter with a little pale hair; hypopygium small, with a slender, black organ extending backward along its ventral surface from the base to beyond its tip. Coxae and femora black; tip of fore coxae and all trochanters yellow; fore coxae with white hairs on the front surface; extreme tips of the femora, the tibiae and most of the tarsi yellow; tips of the fore and middle tarsi and most of the hind tarsi infuscated; middle tibiae with the usual bristle near the knee; hind tibiae with several on the upper side and one larger one on the outer side near the knee; pulvilli of fore and middle tarsi considerably enlarged; femora with the usual hairs on the lower side. Tegulae, their cilia and the halters yellow. Wings hyaline; first vein does not reach quite half way to the tip of the second vein; third and fourth veins nearly straight and parallel beyond the cross-vein.

Described from one male from Delaware Co., Pa., May 21st. (taken by E. T. Cresson, Jr.)

Type in the collection of the American Entomological Society. Type No. 6070.

Two females that seem to belong with this male have the palpi and antennae smaller, and the pollen of the face more grayish, the pollen of the thorax thicker and the thorax with coppery reflections. Taken on the same date and at the same place as the male.

This species is very much like *aldrichi,* but the color is a pure green, the face appears white in all directions and the third and fourth veins are not bent as in that species.

29 Diaphorus sodalis Loew.

Diaphorus sodalis Loew, Neue Beitr., viii, p. 57; Mon. N. Am. Diptera, ii, p. 163.

Male: Length 4 mm. Eyes widely separated by the front; antennae small, black, arista apical. Thorax and abdomen dark metallic green; thorax distinctly pollenose; bristles at the tip of the abdomen conspicuous. Coxae and femora black; tips of the fore and middle femora and all tibiae yellow; pulvilli of fore tarsi moderately enlarged. Halters and tegulae pale yellow, the latter with black cilia. Wings tinged with gray.

I have seen four specimens of this species; one sent by Prof. J. M. Aldrich, taken in Polk County, Wis., which was presented to him by Prof. C. Fuller Baker; one from Mr. Harbeck which he took at Roxboro, Pa.; one in the Cornell University collection from Black Rock Mountains, Ga.; and one that I took at Springville, Erie County, N. Y., June 7, 1914; this last specimen has the cilia of the tegulae more brownish when viewed from behind.

30 Diaphorus trivittatus n. sp.

Male: Length 2.5 mm. Face about as broad as long, thickly covered with gray pollen; front about as broad as the face and as thickly covered with gray pollen; antennae small, black, inserted at or below the middle of the eyes, third joint very small; arista dorsal; palpi rather large, yellow, brownish at base. Dorsum of the thorax green, the gray pollen in some specimens quite thick, in others scracely apparent; dorsum with three coppery vittae, one well defined central vitta, and a wider, poorly defined vitta on either side, these vittae do not reach the scutellum; pleurae black with dark brown pollen which is not very noticeable; bristles of the thorax large. Abdomen greenish black, rather short and thick for this genus; bristles at the tip of moderate size; hypopygium small, its appendages scarcely visable. Coxae and femora black, trochanters, extreme tips of femora, tibiae and tarsi brownish yellow to brown; tarsi rather darker brown than the tibiae; in one male the hind tibae are almost black; fore and middle coxae with long black bristle-like hairs on the front surface; fore tibiae with a small bristle near the base on the front side; middle tibiae with two large bristles on the front surface, one near the base and one at the middle; fore femora with a few bristle-like hairs near the tip; middle and hind femora with only delicate hairs below; pulvilli of fore tarsi considerably enlarged, those of middle and hind tarsi not enlarged. Halters and tegulae pale yellow, cilia of the latter black. Wings grayish hyaline, a little darker in front of the third vein; veins black; first vein reaches about two-fifths the distance to the tip of the second.

Female: Agrees with the male in color, and in the arrangement of the hairs and bristles, but the fore pulvilli are not enlarged.

Described from four males and four females which I took at Bradentown, Fla., in March. Type in the author's collection.

31 Diaphorus dubius Ald.

Diaphorus dubins Aldrich, Trans. Ent. Soc. of Lundon, Pt. iii, p. 324.

Male: Length 2.4-2.7 mm. Face and front green, of about equal width, and thickly covered with pollen, but the ground color showing through when viewed from in front; antennae black, small, third joint very short, rounded at tip; arista apical. Thorax bronze green, the posterior end and the scutellum pure green; dorsum with a trace of a coppery vitta in the center. Abdomen metallic coppery, the bristles at the tip distinct in some specimens and not so in others; hypopygium small, its appendages scarcely visible. Coxae and femora black; trochanters and tips of fore and middle femora broadly and hind femora narrowly reddish yellow; tibiae and the first joint of the tarsi yellow; tarsi brown from the tip of the first joint; fore tibiae with a minute bristle on top near the base; middle tibiae with a large bristle near the base on the front side; hind tibiae with a few small bristles on the upper surface; fore and middle tarsi longer than their tibiae; hind tarsi a little shorter than their tibiae and with the second joint only a little shorter than the first. Halters and tegulae yellow, the latter with black cilia. Wings grayish hyaline; first vein reaching about one-third the distance to the tip of the second.

The above characters are taken partly from the original description and partly from a type specimen kindly loaned me by Prof. J. M. Aldrich.

St. Vincent, W. I., and also from Grenada.

32 Diaphorus palpiger Wheeler.

Diaphorus palpiger Wheeler, Psyche, June, 1890, p. 360.

Male: Length 2.75 mm. Eyes widely separated by the front; palpi as long as the face, glistening white with golden yellow bases; antennae small, black; arista subapical. Thorax and abdomen golden green; abdomen less golden than the thorax which has a thick layer of yellow dust (in the specimens I have seen the dust is more gray than yellow). Coxae and tarsi black; femora and tibiae greenish black, shining; knees yellow. Halters and tegulae yellow, the latter with yellow cilia. Wings grayish hyaline; first vein reaching more than one-third of the distance to the tip of the second vein.

Described from Milwaukee County, Wis.; I took a specimen at Toronto, Ont., August 8th, and another at Lewiston, N. Y., May 30th; Prof. J. M. Aldrich sent specimens from Viola, Idaho, and Wells, Nev.; there were three specimens in the Cornell University collection material, one taken at Fulton, Cal., May 15th; one from Revelstake, Colo., July 1st, taken by J. C. Bradley; and one without locality label which has a coppery vitta on the dorsum of the thorax. I cannot detect any difference in these western specimens except that the palpi are less yellow at base and the pollen on the thorax is more gray.

33 Diaphorus triangulatus n. sp.

Male: Length 2.5 mm. Face broad, longer than wide, covered with silvery pollen; palpi large, fully one-half as long as the face, nearly oval, about as wide as long, somewhat pointed at tip, pale yellow with silvery pollen; front bright green with the pollen of the face extending a little above the antennae on the sides; antennae black, third joint large, somewhat triangular, as long as the two basal joints (Fig. 7); arista inserted above the point of the third joint; cilia of the laterial and lower orbits white. Thorax and abdomen metallic green, sometimes with coppery reflections, the former with a little gray pollen along the front and sides of the dorsum; hairs of the abdomen brown on the dorsum and white on the venter, bristles at the tip small, scarcely noticeable; hypopygium small, its appendages also small. Coxae black, fore pair with white hairs on the front surface; femora metallic green with yellow tips, the usual row of hairs on the lower outer edge very short, those on the fore femora longest; tibiae and tarsi yellow, in one specimen the tarsi are scarcely darker towards their tips, in the other the distal third of hind tibiae and their tarsi are brownish; the bristle on the front side of the middle tibiae near the base is rather large; bristles of the hind tibiae small; pulvilli of the fore tarsi a little enlarged. Tegulae, their cilia and the halters yellow. Wings hyaline; the first vein does not reach quite half the distance to the tip of the second vein.

Two females that appear to belong here have the palpi normal but still rather large, yellowish with thinner white pollen; the face is black when viewed from in front and has a transvers suture below the middle; third antennal joint small; front and thorax more coppery than in the male; wings with the first vein shorter than in the male (this is often the case in this genus).

Described from two males and two females from Lewiston, Idaho. Type in the collection of Prof. J. M. Aldrich.

34 Diaphorus amoenus Ald.

Diaphorus amoenus Aldrich, Kans. Univ. Sci. Bull., vol. i, p. 86.

Male: Length 2.5 mm. Eyes widely separated by the front; pollen of the face yellowish; antennae black, third joint pointed; arista apical; palpi yellowish white, very large, about a third as long as the height of the head and two-thirds as wide as long. Thorax and abdomen bright green, somewhat golden, the former a little dusted; bristles at the tip of the abdomen distinct. Halters and cilia of the tegulac yellowish. Fore coxae, femora and tibiae yellow; middle and hind coxae brown; pulvilli of fore tarsi elongated. Wings tinged with gray.

Grenada, W. I.

35 Diaphorus parvulus Ald.

Diaphorus parvulus Aldrich, Trans. Ent. Soc. of Ludon, pt. iii, p. 321.

Male: Eyes widely separated by the front; antennae black, third joint rather large; arista subapical. Thorax shining green. Abdomen bronze green, venter yellowish, without stout bristles at tip. Fore coxae, apical part of middle coxae, femora, tibiae and base of tarsi yellow; fore pulvilli enlarged; bristle at base of middle tibiae very large. Wings tinged with yellowish.

St. Vincent, W. I.

36 Diaphorus variabilis n. sp.

Male: Length 2.75-3.2 mm. Face not very wide, covered with white pollen; palpi yellow; proboscis black; front fully as wide as the face, green, thickly covered with white pollen, which is thinner towards the vertex; antennae black, third joint of moderate size, rounded at tip; the long arista almost apical. Thorax metallic green with gray pollen, which is thickest along the front and sides of the dorsum and on the edges of the scutellum; pleurae green with white pollen. Abdomen concolorous with the thorax but with slight bronze reflections, especially along the anterior and posterior edges of the second segment; hairs of the abdomen black; bristles at tip distinct; venter slightly yellowish; hypopygium very small, almost concealed, the only visible appendage is a rather long central filament. Fore coxae with silvery pollen and short yellow hairs on the front surface and black bristles at tip; middle and hind coxae black with yellow tips; femora and tibiae yellow; fore femora with a few bristle-like hairs near the tip of the lower outer edge; middle femora with about four hairs on the front at tip; hind femora with a few longer hairs near the tip and a preapical bristle, which is not very conspicuous, close to the tip on the outside; fore tibiae without bristles except a very small one on top near the base; middle tibiae with two bristles, one long slender one near the base on the front and a very minute one near the middle on top; hind tibiae with several bristles on the upper surface; all tarsi blackened from the tip of the first joint; front tarsi fully one and one-half times as long as their tibiae and with their pulvilli enlarged; pulvilli of middle and hind tarsi only slightly enlarged. Halters and tegulae pale yellow, the latter with yellow cilia. Wings rather long and not very wide, grayish hyaline, veins brown, yellow at the root of the wings; first vein reaching a little more than one-third of the distance to the tip of the second.

Female: Two females that seem to belong here do not differ from the male except that the middle coxae are nearly half yellow.

Described from one male and two females taken at Bradentown, Fla., in March; one male taken by Dr. J. C. Bradley at Lavender, Floyd County, Ga., August 23d, has slight indications of a central vitta on the dorsum of the thorax; while one taken by Mr. Nathan Banks at Chain Bridge, Va., on September 17th, has a sharply defined vitta; one male which I took at North Evans, Erie County, N. Y., August 16th, differs from the others in having the pulvilli slightly more developed. Type in the author's collection.

37 Diaphorus subsejunctus Loew.

Diaphorus subsejunctus Loew, Cent., vi, p. 83.

Male: Length 2.5-3 mm. Eyes narrowly separated by the front; antennae small, black. Thorax and abdomen green, the latter with golden reflections, and the former with thin white dust. Fore coxae and feet yellow; middle and hind coxae black, cilia of the tegulae pale. Wings cinerous.

Cuba, W.I.

I do not think this species has been recognized since described; it differs from *variabilis* n.sp. by having the eyes narrowly separated.

38 Diaphorus flavipes Ald.

Diaphorus flavipes Aldrich, Trans. Ent. Soc. of London, pt. iii, p. 323.

Male: Length 2-2.4 mm. Eyes contiguous on the front; antennae small, brownish; arista almost apical. Thorax green, little dusted, smaller bristles and tips of larger ones rusty reddish. Abdomen shining bronze green, venter yellowish, hairs of the abdomen yellowish, apical bristles absent. Coxae, femora, tibiae and tarsi yellow; middle coxae black at base; fore pulvilli enlarged. Halters large, sulphur yellow; tegulae brownish yellow with yellow cilia. Wings yellowish, with yellow veins; first vein reaching slightly more than one-third of the distance to the tip of the second and somewhat distant from the costa.

W. I.

39 Diaphorus mundus Loew.

Diaphorus mundus Loew, Neue Beitr., viii, p. 57; Mon. N. A. Diptera, ii, p. 161.

Male: Length 3 mm. Eyes contiguous on the front; antennae yellowish with the third joint small; arista nearly apical. Thorax and abdomen light metallic green, the former with thick ochre yellow dust. Coxae and feet yellow; pulvilli of fore and middle tarsi considerably enlarged. Halters and tegulae yellow, the latter with black cilia. Wings grayish hyaline.

Type location Pa.; N. J. (Smith Cat.); Charlotte Harbor, Fla., (Johnson); Drayton, Idaho (Aldrich Cat.); I found this the most abundant species of the genus at Bradentown, Fla., in March, 1913, taking twenty specimens during the month.

40 Diaphorus deceptivus Ald.

Diaphorus deceptivus Aldrich, Biologia, Diptera i, p. 346.

Male: Length 2.7-3 mm. Eyes narrowly contiguous on the front; arista almost apical; face blackish; antennae small, black. Thorax globose, bright green; abdomen dark golden green, apical bristles scarcely perceptible; hypopygium very small. Legs yellow; middle and hind coxae infuscated for half their length; fore pulvilli rather large, hind ones smallest; tarsi scarcely infuscated towards their tips. Halters yellow; tegulae infuscated, their cilia blackish but appearing yellowish in certain lights. Wings yellowish.

Mex.

Prof. Aldrich says in the Biologia "*D. deceptivus* seems to be related to *D. subsejunctus,* Loew, of Cuba; but differs in having the front of the male obliterated by the contiguity of the eyes, the cilia of the tegulae darker and the posterior tarsi more infuscated." He was somewhat doubtful of the validity of his species, but only a comparison of a series of both species would establish their identity; until such a comparison can be made they must be considered distinct.

41 Diaphorus femoratus n. sp.

Male: Length 3.2 mm. Face broad, longer than wide, covered with silvery pollen, but appearing black in certain lights; palpi small, yellowish, brown at base (antennae missing) front narrow, not more than one-fourth the width of the face, ground color green but so thickly covered with whitish pollen as to be almost concealed except at the vertex; orbital cilia white except a few of the uppermost. Thorax green with thin gray pollen on the dorsum; pleurae more thickly covered with pollen, and with two or three white bristle-like hairs above the fore coxae. Abdomen bronze green, or more bronze black, with long pale hairs on the sides below; hypopygium small with minute appendages (in the described specimen there are only two short bristles at tip). All coxae and the middle and hind trochanters black; fore coxae with minute white hairs on the front surface; middle coxae with several long yellowish hairs on the front surface, these hairs about as long as the coxae; femora, tibiae and tarsi yellow; the tarsi brownish towards their tips; hind tarsi darkest; pulvilli of fore and middle tarsi considerably enlarged; hind femora with a poorly defined brown band before the tip, the apex being broadly yellow. Tegulae, their cilia and the halters pale yellow, the cilia however appears brownish in certain lights. Wings grayish hyaline; the first vein reaches a little less than half way to the tip of the second, costa slightly thickened beyond the tip of the first vein.

Described from one male taken at Opelousas, La., April. Type in the collection of Prof. J. M. Aldrich.

Easily recognized by the narrow front, yellow femora and the brown band on the hind femora.

Change of Preoccupied Name.

On page 166 in key under 40 for femoratus read australis.

On page 194 top line for femoratus read australis.

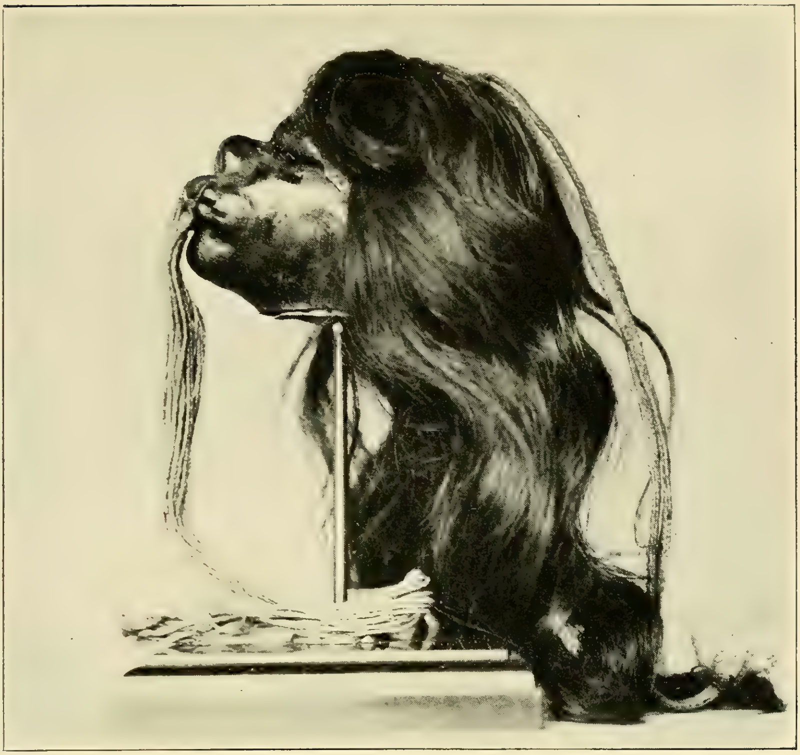
A JIVARO WAR TROPHY

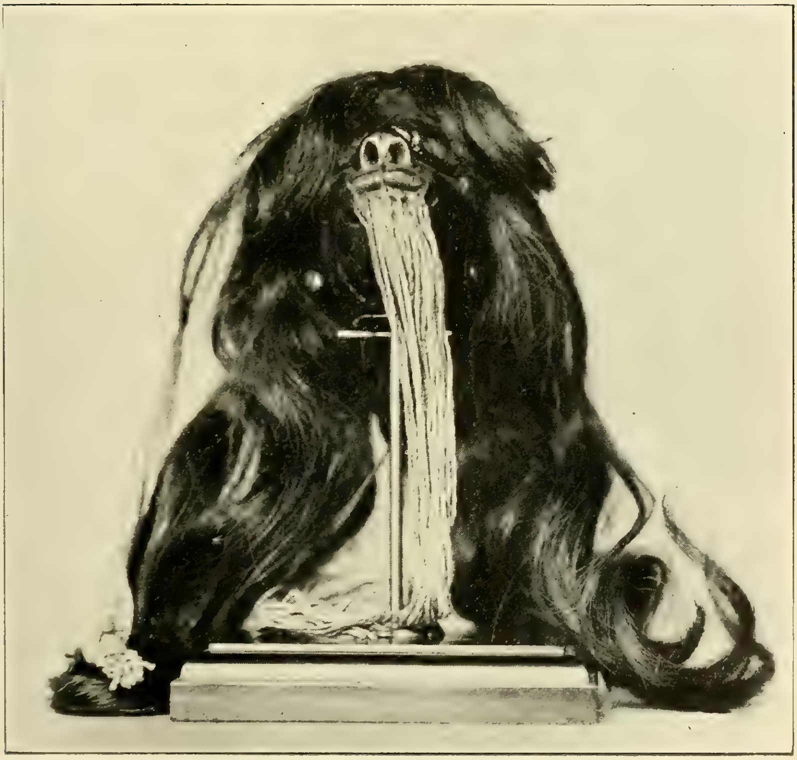
Human Head artificially shrunken by the Jivaro Indians.

In the Museum of the Buffalo Society of Natural Sciences.

The Jivaros, living upon the tributaries of the upper Amazon in Ecuador and Northern Peru are savages of a low type, living by hunting and by war, using for their arms lances and blowguns with poisoned arrows. They dry and preserve their enemies' heads and also those of their own chiefs. An interesting account of this is given in a letter from Frank G. Carpenter, whose information was received at Lima, Peru, in 1913, from Mr. M. Bell Taylor of Boston, who had just returned from an expedition down the eastern slopes of the Andes into the Amazon Valley. He said, "After killing a man they cut his head off close to the shoulders and as soon as they reach camp they open it and take out the bones of the skull. The skin of the head is then sewed together from the crown to the base of the neck. It is now a kind of bag. This is filled with hot sand, but is kept as far as possible in its original shape. It is pressed inward during the drying, the sand being changed from time to time, until the head is reduced to one-fourth or one-fifth the original size. Before beginning the curing, the skin is painted with the juice of the huito, a fruit that looks much like an aguacate pear. This juice is a leather preserver. It is smeared over the head inside and out. As the head grows smaller a stone of the shape of a small skull is inserted and the skin is worked down upon it. This stone regulates the size of the head when it is cured. It is taken out before the skin has grown too hard, but after its features are fixed. The head is then hung up over the fireplace and allowed to cure in the smoke."

Mr. Taylor describes the Jivaros as a well made, good looking, superstitious people, who are polygamists, some of them having seven or eight wives. Their population is kept down by fierce family feuds.

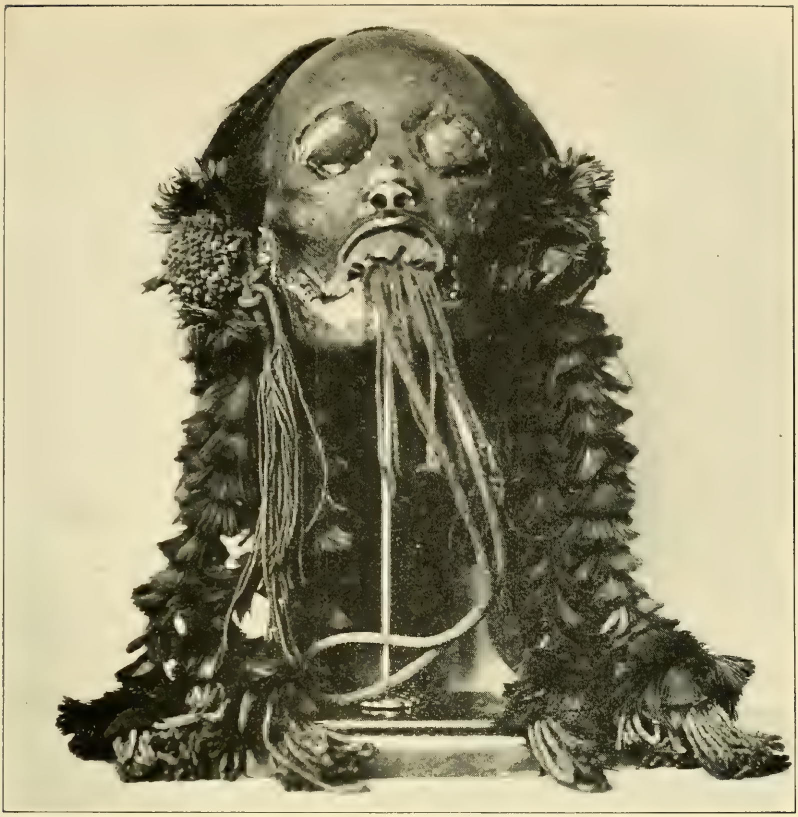


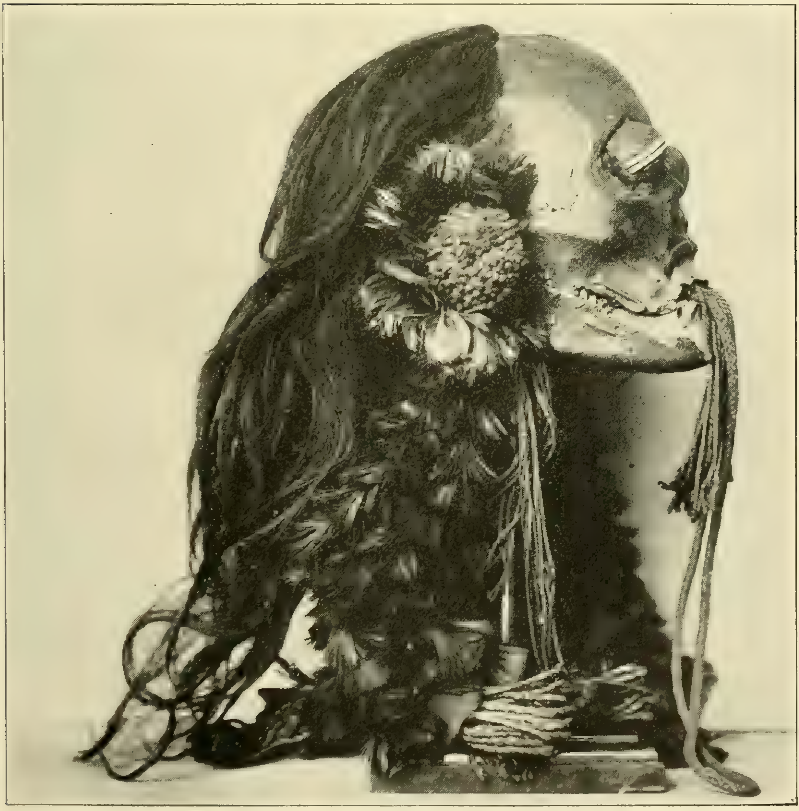


A MUNDRUCU MUMMIED HEAD TROPHY.

In the Museum of the Buffalo Society of Natural Sciences.

These human head war trophies were formerly prepared by the Mundrucus, a powerful tribe of Brazilian Indians, living to the south of the river Amazon on the river Tapajos, near its lower falls, and westward to the branches of the Madeira. In former days they tattooed the face and body in a peculiar manner, and preserved as trophies the heads of their enemies, prepared by smoking them over a fire, filling the eye-sockets with ornamented balls of rubber. They are said to be physically and morally one of the finest of South American races and are agriculturists, but bold warriors. They conquered their neighbors, the Muras in 1788, and in 1803 made peace with the whites and have ever since been their faithful friends. They are now partly civilized and are much employed as rubber gatherers.





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THE HABITAT OF THE EURYPTERIDA

BY

MARJORIE O'CONNELL, PH.D.

BUFFALO, NEW YORK
1916

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THE HABITAT OF THE EURYPTERIDA[1]

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INTRODUCTION

It has been the custom to consider that all fossils are the remains of marine organisms unless obvious and indisputable evidence of their fluviatile, lacustrine, or terrestrial habitat is available; a fossil found without any other associates has been held to be marine until proved to be otherwise, but never has the suggestion been made that such a fossil was fluviatile until proved to be marine. Yet such a suggestion would be most logical, and, as we shall see, it would be far more natural than the one usually made. The early fish have always been considered normally marine, though recent studies of the character of the sediments in which their remains occur has led many of the former advocates of the marine habitat to concede that the earliest fishes lived in non-marine waters, perhaps lacustrine, but most probably fluviatile. Similarly, limestone faunas were at one time referred without question to a marine origin, but we now know that limestones of purely marine organisms may be formed by eolian deposition, as in the case of the Miliolitic limestone of the Kathiawar Peninsula of Western India (Grabau, **87,** 574).[2] There is thus no *a priori* reason for implicitly accepting the marine origin of all those rocks for which it has been claimed, nor for believing that all fossils found in the Palaeozoic rocks, with the exception of freshwater molluscs, plants, and insects, are the remains of marine plants or animals. Just as there is a growing tendency at the present time to recognize the importance of the wind and of rivers as agents of transportation and deposition in the past, so there is noticeable an awakening from the old belief that all fluviatile organisms began their life in the sea, and only after countless ages of evolution in that realm, migrated first into brackish water and then into the rivers.

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[1] This paper was awarded the Walker First Prize by the Boston Society of Natural History in May, 1914.

[2] Throughout this paper numbers in parentheses will refer to the bibliography at the end, p. 257; the full-face type referring to the titles with the same number, the light-face numbers giving page reference in the particular article.

The present paper deals with the habitat of a class of crustaceous animals widespread in the Palaeozoic and confined to it. The Eurypterida belong to the subclass of the Merostomata in the class Acerata of the phylum Arthropoda. Their nearest relatives are the limulids and scorpions with which latter group they have been classed by certain authors.

While it is generally accepted that some eurypterids lived in fresh water, the majority of palaeontologists at the present time still maintain that the early periods of the racial history of these organisms were passed in marine waters and that it was only, indeed, after their acme in development had been reached that these merostomes, becoming at first euryhaline, finally forsook the sea altogether and lived in rivers and in brackish water bodies until they became extinct at the end of the Palaeozoic. The evidence set forth in support of this hypothesis is so plausible that many have been led to think that there is a large and convincing array of facts sufficient to furnish an indisputable proof that the eurypterids lived during at least a part of Palaeozoic time in marine waters. It was with the purpose of showing that such a proof was really non-existent, and that the observed facts can also, and perhaps more rationally be accounted for in another way, that the present paper was undertaken. The author proposes to formulate a few of the principles which must be borne in mind in considering such a problem, and to point out the inconsistency in the lines of argument generally given to prove that the eurypterids were originally marine organisms. After a review of all the evidence available, the attempt will be made to judge it impartially and to determine which interpretation is really called for by the facts. The first chapter contains a record of facts, without comment; they are the data from which deductions are later made and of which interpretations are offered. These facts include: A, the distribution of all known species of eurypterids throughout the world; B, the horizons in which the remains occur, with particular reference to the facies exhibited and to the exact stratigraphical position; C, the mode of occurrence of the remains, whether well preserved or fragmentary, whether a single fragment or a large number of individuals; and finally, D, the other fossils, if there are any, which occur associated with the eurypterids. These facts are all summarized in tables I-III on pp. 37-49 and in the list of faunal associates on pp. 84-91. The second chapter is a résumé of the various opinions which have been held regarding the habitat of the Eurypterida. The next three chapters (III, IV and V) deal with the three chief lines of evidence which may be adduced to determine any fossil habitat, namely, the bionomic characters of the faunas, the lithogenesis of the formations in which the remains occur, and the type of migration and dispersal, marine or fluviatile, indicated by the relations existing between species and genera in synchronous faunas and by the phyletic relationships in successive horizons. In these three chapters general principles are first discussed and criteria are established for recognizing various types of habitats, sediments, and fossil faunas; the application of these criteria to the eurypterid problem is then given in detail. The conclusion reached by the author after the study of all available data and in the light of manifold theoretic considerations is that: *the eurypterids throughout their entire phylogenetic history lived in the rivers.*

Aside from the work done on the literature, a large amount of material has been studied, including hundreds of typical specimens of eurypterids, thin sections of some of the waterlimes, the collections of the rock types from the eurypterid-bearing horizons of Europe collected by Professor A. W. Grabau and now in the Palaeontological Museum of Columbia University; further, a number of the best sections in the field have been visited. When the present paper was nearly finished there appeared Clarke and Ruedemann's exhaustive Monograph on the Eurypterida of New York (**39**), which, with Woodward's Monograph of the British Fossil Crustacea, gives us the most illuminating and comprehensive work on the Eurypterida. Many important points in the ontogeny and phylogeny of the eurypterids are here set forth for the first time, and all of the North American species are described in great detail and figured in a volume of plates that surpass all former illustrations.

I wish to express my thanks to Dr. R. Ruedemann, who allowed me to study the large collection of New York eurypterids at the State Museum in Albany; to Dr. C. D. Walcott, who showed me the large Beltina fauna and the beautiful specimens of Limulava from the Middle Cambric Stephen shale of Canada in the Smithsonian Institution at Washington, D. C.; and to Mr. McIntosh at the Museum of the Natural History Society, St. John, New Brunswick, for information about the age of the Little River Plant beds and for the privilege of being allowed to inspect the type material from those beds.

To the courtesy and helpfulness of Mr. Henry R. Howland, Superintendent of the Buffalo Society of Natural Sciences, I owe the opportunity of studying every specimen of eurypterid in the museum of that Society. Furthermore, Mr. Howland loaned me a number of specimens to describe, and I was thus able to show the existence of two species of a pulmonate gastropod, Hercynella, in the Bertie waterlime. It was because of Mr. Howland's interest in papers dealing with the geological problems of the Buffalo region that the present contribution appears in the *Bulletin of the Buffalo Society of Natural Sciences*.

With the fullest appreciation for the inspiration and guidance which I have received, I gladly acknowledge my indebtedness to Professor Amadeus W. Grabau. He was one of the first to advocate the fluviatile habitat of the eurypterids and one of my earliest geological recollections was of a discussion between him and a number of men who argued for the marine habitat, a discussion to which I listened with the utmost interest although I was then not in a position to weigh the evidence brought forward on either side. More than four years ago Professor Grabau suggested that I take up the problem, with the purpose of marshalling all of the available evidence in proof of an hypothesis which he had strong theoretic reasons for believing to be true. Throughout the work I have profitted by the helpful criticisms and keen suggestions of a man who has made such problems his specialty for twenty-five years, and without whose assistance this paper certainly could not have been written. The method of treatment which I have used is based upon the principles of interpretational geology expounded in the Palaeontological Laboratory of Columbia University, and with the hope that this paper shall not prove unworthy of the teachings there set forth, I informally dedicate it to the American School of Philosophic Geologists, among the leaders of whom Professor Grabau stands so preëminent.

CHAPTER I

Systematic Review of the Occurrence of the Eurypterida in Each Period from the Pre-Cambric Through the Permic

INTRODUCTORY

From all over the world there have been recorded fourteen genera and between 150 and 160 species of eurypterids. Of these considerably more than half occur in the Siluric, about a third occurring in the Upper Siluric alone. No remains have been found in beds higher than the Permic, and until 1882 it was supposed that there were none below the Siluric. In that year Walcott discovered a few fragments in the Utica shale, of Upper Ordovicic age, and an even more remarkable fauna in the Pre-Cambric Belt Terrane of Montana. In 1901 Beecher discovered an almost perfect eurypterid in the Upper Cambric of Missouri. These discoveries, together with several more recent ones from the Ordovicic, show that the Eurypterida ranged from the Pre-Cambric through the Permic, reaching their acme in numbers, development and diversity of types in the Upper Siluric. In the following review of the occurrence North America alone will be considered first and then the rest of the world. Until the *Monograph on the Eurypterida of New York* appeared there was no one book containing all the information about the North American species, and it was necessary for one in quest of such knowledge to search laboriously through state reports and numerous periodicals. Now all the data have been systematically brought together and greatly added to, so that it will be unnecessary to dwell at great length upon the American formations. For the rest of the world, unfortunately, there is no one book to which the student may be referred, so that one is compelled to consult the literature of each country in each continent thus gradually bringing together the work that has been done. Because the foreign periodicals and books now out of print are inaccessible to many, a more detailed account will be given of the distribution, and the nature and correlation of the formations in other countries than is required for America.

NORTH AMERICA

Pre-Cambric. The earliest representative of the eurypterids is *Beltina danai* discovered by Walcott in the Greyson shales in the middle part of the Belt Terrane in Montana. The remains are very numerous, most of them being exceedingly thin films flattened in a calcareous shale and showing no definite surface markings (**288**, 21). Weller has collected specimens from the Altyn limestone at the type locality north of Altyn in the valley of Swift Current Creek, Montana, at the base of the Appekunny Mountains where the remains are embedded in a fine calcarenyte matrix and show surface markings (**288**, 40, pl. 7, fig. 4). Specimens have also been collected from the Altyn limestone at about the same horizon near Johnson Creek on The Continental Divide, Alberta, Canada. These show surface markings, and have been referred by Walcott to *B. danai* (**288**, 40, pl. 7, figs. 2, 2a, 3).

In a recent communication from Dr. Walcott, I have his statement about the occurrence of the merostome remains in the different sections. In the southeastern area of the Big Belt Mountains he found a series of sandy shales and sandstones between the top of the Newland limestone and the base of the Greyson; these carried Beltina. In the sections in the Little Belt Mountains Walcott found it difficult to determine whether the shales carrying Beltina belonged to the Greyson or to the Newland. In the Northern Montana section the merostome remains are found in the lower portion of the Altyn limestone, so that, concludes Walcott, "the correlation on the basis of fossil evidence is that the Greyson and Altyn are about the same age."[1] The fossils from the Altyn limestone were identified by Walcott as *Beltina danai*, and Clarke and Ruedemann agree that the fragments are remains of merostomes. They are, however, skeptical about the correlation of the Altyn with the Belt terrane and they are justified in this skepticism so long as the correlation is based upon the fossils alone, for if the organic remains in the Belt terrane are not eurypterids and are not the same as those in the Altyn, then the correlation is unfounded. Furthermore, the palaeontological evidence alone would not be sufficient for correlation, and, if, as I believe, these Pre-Cambric formations are to be regarded as of continental origin, then neither physical nor faunal data will lead to correlations, since the same lithological successions will be repeated time and again in different localities and in addition the synchroneity of river faunas is difficult to establish.

Thus at present it is impossible to say which authority is to be accepted. Walcott plans to do more work on these sections in the course of which he may find better preserved fragments in the Belt terrane, leaving no doubt as to the nature of the organisms; or, he may find other structural and stratigraphic evidence for the correlation. "On the basis of lithologic characteristics," he says, "the Altyn would be correlated with the Newland limestone, and the Grinnell and Appekunny with the arenaceous series above the Newland limestone." But he further points out that "In deposits of the character of those of the Algonkian in Montana, lithologic characteristics are really of very little value over extended areas, as most of the calcareous formations are in the form of great lentils, and these are not comparable with the calcareous deposits of the Palaeozoic."

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[1] Dated February 26, 1915.

CAMBRIC. In the Middle Cambric there are undoubted marine Merostomata, discovered by Walcott in 1910 in the Stephen formation in British Columbia, Canada. He has described two genera, Sidneyia and Amiella, referring them to the Eurypterida in the suborder Limulava. As will be shown later, these forms are not true eurypterids, and need, therefore, no further mention here.

The only unquestionable eurypterid from the Cambric is Beecher's *Strabops thacheri* from the Potosi limestone at Flat River, St. François county, Missouri (**19**, pl. VII). Of this species a single specimen was found for which the genus was erected. It is a nearly complete individual, the dorsal aspect of which is well shown, though none of the appendages are visible. It occurs in a yellowish, argillaceous calcilutyte from one of the lower members of the Potosi. The slab upon which Strabops occurs contains no other organic remains,[2] but Beecher has described a collection made by Nason from these same beds in which there is an abundant marine fauna consisting of fragments of trilobites with a few brachipods and other forms (Hyolithes and a small Platyceras) (**20**, 362, 363). It is to be regretted that Beecher did not, or was not able to specify more exactly the stratum in which he found the eurypterid, for the Potosi limestone in the Flat River section is 350 feet thick, not counting the 106 feet of slates and conglomerate below and another 100 above, all of Potosi age, and of course, it is by no means certain that the marine fossils occurred in the same bed with the eurypterid. In fact, so far as the material is concerned, this seems not to have been the case.

ORDOVICIC. From the Ordovicic until just recently only one occurrence had been noted, that of *Echinognathus clevelandi* Walcott, described from the Utica shale of Holland Patent, New York (**281**), where one cephalic appendage and a portion of a thoracic somite were found. On the same piece of slate with these fragments Walcott found two characteristic Utica fossils, *Leptobolus insignis* and *Triarthrus becki*, and from the same locality comes a large graptolite fauna including *Dendrograptus tenuiramosus*, *Climacograptus bicornis*, as well as *Schizocrania filosa* and *Endoceras proteiforme*.

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[2] The type of this species is in Yale University, but the counterpart of the type is in Columbia University Paleontological Collection, specimen 18122.

Lately there have been some extremely interesting discoveries of eurypterids in the Normanskill and Schenectady shales and sandstones (Black River and early Trenton age, respectively) of the Mohawk and Hudson valleys. Professor G. H. Chadwick has very recently found eurypterid remains in the sandstones of the Broom Street Quarry at Catskill, New York, in the Normanskill beds which until then had yielded only a graptolite fauna. Clarke and Ruedemann have described the species and also the beds from which they come. The eurypterids are very abundant in the sandstones though poorly preserved, but in the intercalated black shales, while less numerous they show better preservation. They are associated with graptolites and plant remains. Six species have been described by Clarke and Ruedemann. *Eurypterus chadwicki*, *Eusarcus linguatus*, *Dolichopterus breviceps*, *Stylonurus modestus*, *Pterygotus ?* (*Eusarcus*) *nasutus*, *P. normanskillensis*. Entire individuals are absent, the fauna being made up chiefly of carapaces.

The first profuse Upper Ordovicic fauna is found in the Schenectady shales (Trenton age), originally referred to the Frankfort. A preliminary notice of these specimens which appeared in 1910 (**38**, 31) shows that these remains "usually in fragmentary condition, abound most freely in fine-grained black shale, intercalated between thick calcareous sandstone beds. . . . . but they also occur in the sandy passage beds between the two. The sandy shales are full of organic remains, partly of the supposed seaweed *Sphenothallus* (*Sphenophycus*) *latifolium* Hall and partly of what appear to be large unidentified patches of eurypterid integument. In the black shales the eurypterid remains are rarer, but their surface sculpture is excellently retained, and here their organic associates are *Climacograptus typicalis* and *Triarthrus becki*. As a result of imperfect retention of these eurypterids in the rocks where they most abound and their sparseness in the shales which have best preserved them, we are still left in ignorance of the full composition of the assemblage, but it is safe to say genera, species and individuals were abundant at this early period and the evolution of distinctive characters . . . . . had progressed to so sharp a differentiation that we are compelled to carry back farther in history, some of the commoner generic designations. These remains in the Frankfort [Schenectady] shale are distributed through fully 1500 feet of strata off a northeast-southwest coast line in an area of maximum deposition." Clarke and Ruedemann have described eleven species[3] *Eurypterus megalops, E. pristinus, E. ? (Dolichopterus ?) stellatus, Eusarcus triangulatus, E ? longiceps, Dolichopterus frankfortensis, D. latifrons, Hughmilleria magna, Pterygotus nasutus, P. prolifica, Stylonurus ? limbatus.*

A few fragments found as early as 1874 in the upper part of the Cincinnati group near Clarkesville, Clinton County, Ohio, were originally described by S. A. Miller (**174**) as *Megalograptus welchi*, under the mistaken supposition that they represented a graptolite, but were later determined by A. F. Foerste to be eurypterid remains. The specimens are much broken, representing two endognathites with one postabdominal segment. They occur in a blue marl three feet above a wave-marked layer of limestone, in the Liberty beds where they are associated with a typical marine fauna mainly of crinoids and some trilobites.

SILURIC. *Lower Siluric or Niagaran.* In the Lower Siluric are several cases of the presence of eurypterid remains in marine formations. Hall's species of *Eurypterus prominens* from the Clinton greenish sandstone of Cayuga County, New York, was described from a single cephalon, and an unidentified species of Eurypterus is recorded from the Arisaig of Nova Scotia (**39**, 87). Whiteave's *Eurypterus (Tylopterus) boylei* from the Guelph dolomites of Ontario is a species founded upon a single somewhat crushed, but otherwise nearly complete individual. It is found in a porous, coarse-grained dolomite, and shows an unusually thickened exoskeleton, a thickening common in other members of the Guelph fauna and indicating, according to Clarke and Ruedemann, extremely saline conditions (**39**, 218).

Quite recently a new eurypterid horizon has been discovered by M. Y. Williams in the shales overlying the Lockport and underlying the Guelph of Ontario, Canada. Along the banks of the Eramosa River between Rockwood and Guelph the top of the Lockport formation is exposed, and is seen to consist of a series of "thin-bedded, dark grey or chocolate brown, bituminous dolomites which at some localities include bituminous shales," and to which Williams has given the name Eramosa beds (**303,** 1).

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[3] *Eurypterus ruedemanni.* This name is proposed for the species called by Clarke and Ruedemann *E. megalops*, that name having been previously occupied by Salter (1859). The fact that Woodward referred Salter's species to Stylonurus does not restore the validity of the name *megalops* for Eurypterus.

The bituminous nature of the dolomites and intercalated shales is indicative of near-shore conditions, and since these succeed the more purely marine facies of the typical Lockport, a shoaling or withdrawal of the sea, with a greater dominance of terrestrial sedimentation, is implied. The fauna is confined within some six inches of the bituminous shales and though fragments of a dozen or more species, including one eurypterid, have been found in abundance, not even generic identifications could be made with certainty. Williams gives the following list (**303,** 3):

Eusarcus logani Williams
Monomorella cf. orbicularis Billings
Orthis ? near tenuidens Hall
Spirifer radiatus Sowerby ?
Anoplotheca ? sp.
Lichenalia concentrica Hall
Orbiculoidea subplana (Hall)
Camarotoechia whitei (Hall)?
Whitfieldella nitida Hall?
Meristina ? sp.
Conularia niagarensis Hall?
Conularia sp.

The *Lower Siluric* occurrences, thus, are in formations containing undoubted and abundant marine faunas, but the eurypterids are represented either by fragments, or, in the case of the Guelph specimen, by a single though nearly perfect individual.

A recent discovery of considerable interest is the finding by Professor Van Ingen of Princeton University, of eurypterid remains in what appears to be the Tuscarora and associated beds of Swatara Gap, Lebanon County, Pennsylvania (**39,** 418, 419). In beds carrying *Arthrophycus harlani ?* he found:

1. *Eurypterus maria,* Large and small carapaces.
2. *Dolichopterus* cf. *otisius.* Medium sized carapace.
3. *Stylonurus myops.* Large and small carapaces .
4. *Hughmilleria shawangunk.* Large carapace.
5. *Pterygotus cf. globiceps.* Small carapace.
6. Swimming leg of a Pterygotus or Hughmilleria.

Another bed labeled 182 B 23 has afforded a carapace not distinguishable from *Eurypterus maria.* A bed, said to occur between a horizon containing what is apparently a Clinton fauna (B 8x) and one containing a Rochester (or Lockport) fauna (B 19x)and numbered B 16 h, contained the following remains:

1. Small carapaces, belonging to species closely related to or identical with *Eurypterus maria, Hughmilleria shawangunk* and *Pterygotus globiceps.*
2. A patch of integument with finely preserved sculpture identical with that ascribed to Stylonurus sp.
3. *Stylonurus myops.* Fragmentary, medium sized carapace.
4. Coxa, probably belonging to Hughmilleria.
5. Small telson of an Erettopterus.

Middle Siluric or Salinan. In the Middle Siluric of North America are several interesting occurrences of eurypterids, and the first appearance of well preserved individuals in large numbers. Specifically indeterminable fragments of Hughmilleria and carapaces of Dolichopterus (cf. *D. otisius*) or Hughmilleria have been found along the Pennsylvania-Maryland border in a hard black shale which is "sandy at the top and pitted by rust-stained worm-tubes" (**267,** 5), and which is interbedded between two sandstone members of the Keefer sandstone member of the McKenzie formation at the base of the Salina.

Of far greater interest and importance, however, are the faunas of the Pittsford and Shawangunk shales of New York and Pennsylvania. At Pittsford, Monroe County, New York, five species (or varieties) of eurypterids have been found: *Eurypterus pittsfordensis* Sarle, *Hughmilleria socialis* Sarle, *H. socialis* var. *robusta* Sarle, *Pterygotus monroensis* Sarle and *Stylonurus* (*Ctenopterus*) *multispinosus* Clarke and Ruedemann. This fauna is represented by numerous individuals, many of them well preserved, and by many fragments, but typical marine fossils are absent from the shales, although crustacea such as *Emmelezoe decora* and *Pseudoniscus roosevelti* occur. The eurypterids are here preserved in a remarkable state of perfection, the fauna being found in two thin layers of the black shales (lower one 1 foot 2 inches thick, upper one 10 inches thick) (**240,** 1082) and the eurypterids are in such abundance that some layers are "literally packed" with the remains. The entire fauna from these beds as reported by Sarle (**240,** 1081) is: Phyllocarida, 2; Synxiphosura, 1; Eurypterida, 6.

In the associated dolomitic layers were found Graptolitida, 1; Annelida (denticles), 3; Brachiopoda, 1; Pelecypoda, 1; Cephalopoda, 2; Ostracoda, 1.

A recent discovery by Professor Gilbert van Ingen has brought to light some eurypterid remains from a loose block found lying in Oriskany Creek, 3 miles south of Clinton, New York. Three carapaces and several other fragments were found, the block also being "full of lingulas and orbiculoideas" (**39**, 421). A new species, *Eusarcus vaningeni* Clarke and Ruedemann was made, to include these specimens which closely resemble *E. cicerops* of the Shawangunk of Otisville and may represent the adult of that species.

From the shale beds in the Shawangunk conglomerate at Otisville, Orange County, New York, a large fauna of eurypterids has been obtained, but other fossils except Ceratiocaris are absent. Here in the Shawangunk Mountains of Eastern New York is a great series 630 feet thick of the Shawangunk grit resting upon the Hudson River shales. The series consists of alternating shales varying from 2 to 6 inches in thickness, and conglomerates or sandstones from 1 to 50 feet thick, the shale bands containing the merostomes. Some of the specimens though only 2.5 mm. long are perfectly preserved and are by far the youngest and smallest yet recorded. In regard to the occurrence Clarke says: "In the Shawangunk section we have a fauna constantly repeating itself through a thickness of 650 feet which elsewhere appears only and briefly at the base of the Salina" (**36**, 303). The perfect specimens are all of young individuals, adults being represented only by fragments. The species recorded are: 1. *Eurypterus maria* Clarke, 2. *Eusarcus? cicerops* Clarke, 3. *Dolichopterus otisius* Clarke, 4. *D. stylonurus* Clarke and Ruedemann, 5. *Stylonurus* (*Ctenopterus*) *cestrotus* Clarke, 6. *S.* (*Ctenopterus*) sp. α, β, γ, 7. *S. myops* Clarke, 8. S. sp., 9. *Hughmilleria shawangunk* Clarke, 10. *Pterygotus globiceps* Cl. and R.

From the middle part of the Shawangunk grit of Delaware Water Gap, Pennsylvania, intercalated black shales similar to those in New York have furnished eurypterids. These were discovered by Mr. Paul Billingsley of Columbia University, who collected a large amount of material and who reports that the fragments are all dissociated, the carapaces commonly occurring by themselves, and separated from the abdominal segments, as if arranged by violent currents. Professor G. van Ingen and Mr. J. C. Martin have also collected extensively from this section. From their large number of specimens Clarke and Ruedemann have been able to identify Nos. 1, 3, 7, 9, 10 of the list of species recorded from the Shawangunk of Otisville, and they make the comment that "Unfortunately, the maceration, already so prevalent in much of the eurypterid material at Otisville, has at the Delaware Water Gap reached such a destructive degree that the shale is filled with a mass of comminuted eurypterid fragments" (**39**, 417).

Upper Siluric or Monroan. The Bertie waterlime of New York of Upper Monroan age has long been famous for the wonderful eurypterid fauna which it contains. This has been found in two localities: (1) in the quarries in North Buffalo, Erie County, and (2) in Herkimer County; there are scattered occurrences of single species in other localities, which will be referred to below. The quarries at Buffalo have yielded the largest number of remains, the specimens having been sent in great numbers to museums all over the world, and the rock has now been so well worked over that probably no new disclosures will be made. For purposes of study of the entire fauna of the Bertie the large collection in the Museum of the Buffalo Society of Natural Sciences offers excellent opportunities. The Bertie contains the largest eurypterid fauna of any one formation in the world, there being recorded fourteen species (**39**, 89) referred to four genera: Eurypterus (5 sp.), Pterygotus (5 sp.), Eusarcus (1 sp.), and Dolichopterus (3 sp.). The specimens are for the most part astonishingly well preserved, but other organisms are extremely rare. In the Museum above referred to are a few specimens of marine organisms obtained from the formation which furnished the eurypterids. One slab of the waterlime about 1¼ inches thick shows on one side an *Orthoceras undulatum* which is very much worn, the siphuncle being exposed and the surface macerated (No. 13310 E 1639 of Buf. Soc. Nat. Sci. Coll.) and on the other side is a well preserved Eurypterus head (11461 E 976). There is one other specimen of *O. undulatum* (13309, E 1638) of a very carbonaceous nature. There are a number of specimens of *Trochoceras gebhardi*, but as a rule these are found in a rock not of the character typical of the Bertie layers bearing the eurypterids. In one case it is arenaceous and not a calcilutyte (13353 E 1682), containing two fragmentary specimens. The slabs containing the Trochoceras do not have eurypterid remains on them, with one exception (13345 E 1674) in which there is a eurypterid claw on a slab showing an imperfect *T. gebhardi*. Associated with the eurypterids are a number of well preserved gastropod shells belonging to a genus which is also known from the Monroe formation of Michigan. This genus is Hercynella and it is represented at Buffalo by two species *H. patelliformis* O'Connell and *H. buffaloensis* O'Connell (**200**).

Seven specimens of *Lingula sp.* Hall occur on one of the slabs. *Leperditia alta* and a large number of pelecypods of the genus Goniophora, but labeled *Leperditia alta* occur on a slab which probably does not come from the Buffalo region, but is more likely from Ohio, judging from the lithological character. Finally, there are a number of specimens of *Ceratiocaris acuminata* associated on the same slabs with the eurypterids and showing a preservation as perfect as theirs, these being the only fossils which do show this. Number 11453 E 968 contains *Eurypterus lacustris* and a large specimen of *Ceratiocaris acuminata*, the former with head shield and body separated, but both beautifully preserved. The plant remains are important, for many of the specimens of Eurypterus are found lying embedded in *Buthotrephis lesquereuxi*, and in one case there is a large mass of Buthotrephis at the side and on top of a Eurypterus (13329 E 1657). (Some of these specimens of Buthotrephis are now regarded as graptolites.) There are three specimens of the plant ? form, *Chondrites graminiformis*, two of which are excellently preserved (13273 E 1602 and 13312 E 1641 Pohlman's type[4]). At Waterville, Oneida County, New York, a small scorpion *Proscorpius osborni* Whitfield has been found in a good state of preservation in the Bertie waterlime.

A remarkable fact in connection with the occurrence of the eurypterids in the Bertie is their distribution in two distinct basins or "pools," the "Herkimer pool" on the east and the "Buffalo pool" on the west. These pools, while prolific in species and individuals, have, however, only two species in common, so far as published data show. Further search may reveal more forms in common, but it is certainly a significant fact that the abundantly represented species of the two areas are distinct, when the horizon is the same, and the localities only a few hundred miles distant. The following list gives the specimens for each pool, representative or identical species being apposed (**39**, 92 footnote):

Buffalo Pool	*Herkimer Pool*
1. Eurypterus lacustris	1. Eurypterus remipes
2. E. lacustris var. pachychirus	
3. E. pustulosus	
4. Eusarcus scorpionis	
5. Dolichopterus macrochirus	5. Dolichopterus machrochirus
6. D. siluriceps	6. D. testudineus
7. Pterygotus buffaloensis	7. Pterygotus macrophthalmus
8. P. cobbi	8. P. cobbi
9. P. grandis	9. Proscorpius osborni

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[4] Figured in Buf. Soc. Nat. Hist. Bull., Vol. V, p. 31 (220).

"The species common to both are *Dolichopterus macrochirus* and *Pterygotus cobbi*, both of which are quite rare, while the predominant species in both places are unlike. It is not believed that these differences necessarily express distinct stratigraphic horizons, as both lie near the top of the waterlime succession, but rather indicate original regional separation into distinct lagoons or pools . . . . which we may assume to have been synchronous. There is, in the face of the difference suggested, a certain degree of approximation in the two expressed by such vicarious species as *E. remipes* and *E. lacustris*, *P. macrophthalmus* and *P. buffaloensis*, which may well mean distinctions due to geographic isolation. The Herkimer pool is well restricted and its faunule cannot be traced very far towards the west; the Buffalo *E. lacustris*, however, appears alone as far east as Union Springs, Cayuga County, and as far west as Bertie, Ontario. Another difference in these faunas is the preponderating great size of all the species in the Buffalo pool, and, by contrast, the small size of and abundant young among the Herkimer county species; . . . . That the smaller creatures lived in conditions of shallower water is evinced by the sun-dried and cracked rock surfaces of their matrix, while such evidences are wanting in the Buffalo pool . . . . " (**39**, 92). *Eurypterus remipes*, one of the common forms in the Herkimer pool, is also obtained from the Rondout waterlime above the Cobleskill at Seneca Falls, Seneca county, New York.

The Manlius limestone of uppermost Monroan age has yielded fragments of *Eurypterus microphthalmus* from various localities in New York and also from Ohio. The type, a single cephalon, came from a loose boulder near Cazenovia, Madison county, New York, containing also fragments of *Spirifer vanuxemi* from which the age of the boulder was determined. One nearly entire specimen was found in the drift of Onondaga Valley, near Syracuse, New York. Of the number of carapaces now in the New York State Museum, one was collected "in the town of Litchfield in Manlius limestone, not less than 100 feet above the Eurypterus horizon in the Bertie waterlime" (**39**, 194). Professor Whitfield's type of *E. eriensis* (now regarded by Clarke and Ruedemann to be the same as *E. microphthalmus* Hall) came from the hydraulic limestones, the Put-in-Bay dolomite, of Beach Point, Put-in-Bay Island, Lake Erie, Ohio.

There is one more Siluric fauna to be noted and that is the one in the Kokomo waterlime of Indiana. Clarke and Ruedemann, following Schuchert correlate the Kokomo with the Noblesville of

Northern Indiana (Schuchert **255**, 467), which is in turn correlated with the Lockport of New York. The latter correlation may stand, but the former is not supported by palaeontological evidence. In a private communication from E. M. Kindle, who has written quite an extensive paper on the Stratigraphy of the Niagara of Northern Indiana (**139**), the following comment is made in reference to the statement that the Kokomo eurypterids are found in the Lockport-Noblesville horizon: "This reference of course is an unfortunate error and is presumably based upon a correlation of the Kokomo limestone and the Noblesville limestone of Indiana which is undoubtedly erroneous. There is practically nothing in common between the faunas of the Noblesville and the Kokomo. The lithology of the beds is quite as unlike as their faunas so that there is absolutely no ground for correlating these two distinct faunas." Since Kindle has done considerable work in the region and made extensive collections of the fossils, his statement is of importance. Palaeontologically it appears that the Kokomo is surely not earlier than Salinan and is more probably Monroan, corresponding to one of the waterlimes in New York.[5] The eurypterid remains are very thin films, scarcely more than impressions, so that scale markings often are not visible. The preservation is not nearly so perfect as in the Bertie waterlime of New York. There are at least 40 feet of limestone, characterized by thin lamination of bedding planes and the presence of eurypterids. Above this horizon is a series of limestones, not thinly laminated, containing a rather rich brachiopod fauna, but with the eurypterids the only other fossils are ceratiocarids. The brachiopod fauna, so far as is possible to learn from the literature, occurs at a different level from that in which the merostomes are found (Foerste, **67**, 6–8). Four species have been reported from the merostome beds: *Eurypterus ranilarva* Cl. and R., *E.* (*Onychopterus*) *kokomoensis* Miller and Gurley, *Eusarcus newlini* (Claypole) and *Stylonurus* (*Drepanopterus*) *longicaudatus* Cl. and R., giving altogether a fairly large fauna and one that is sufficiently well preserved for purposes of characterization.

Devonic. The Devonic of America shows a great decline of the eurypterids, so far as we can judge from the fossil record, for, while in the Siluric there had been an ever-increasing number of species and of individuals, in the Devonic, on the other hand, there are no representatives in the Lower and Middle, and it is not until the very top of the Upper that a few stragglers are found. The first, a specifically undetermined Pterygotus mentioned by Billings, is from the Grand Greve limestone of Lower Devonic age. Remains of Pterygotus have also been found in the lower marine Devonic at Dalhousie. Finally, near Campbellton, New Brunswick, "in some indurated limestones containing fish remains of probably Upper Devonic age" are also eurypterid remains which Clarke and Ruedemann have described as *Pterygotus atlanticus.* An extremely incomplete and problematic form is a two-jointed fragment from the lower beds of the Portage sandstones of Italy, Yates County, New York. Originally described by Dawson as a plant (*Equisetides wrightiana* Dawson), it was later placed among the eurypterids by Hall as *Stylonurus* (?) *wrightiana* and is now so recognized by Clarke and Ruedemann. There is but a single fragment, part of a jointed appendage apparently. A number of fragments of Stylonurus, originally described as *Stylonurus excelsior* by Hall and which Beecher used in making the restoration which he called *Stylonurus lacoanus*, have all been united by Clarke and Ruedemann under the species *Stylonurus* (*Ctenopterus*) *excelsior.* There are only two specimens, one a complete carapace from the Catskill beds at Andes, Delaware County, New York, and another more fragmentary carapace from the same formation in Pennsylvania. *Eurypterus beecheri* Hall described from the Chemung of Pennsylvania has proved to be the same as *Stylonurus beecheri.*

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[5] The brachiopods described by Foerste have a distinctly Monroan aspect.

Mississippic. From the Waverly beds of Warren, Warren County, Pennsylvania, a single eurypterid was described by Hall and Clarke in 1888 as *Eurypteris approximatus.* No complete description of this form is given anywhere, but the figure in the *Palaeontology of New York*, Volume VII, plate 27, figure 6, (**106**), shows the one specimen that has been found in which there are the cephalon and nine somites. This form is regarded by Clarke and Ruedemann as one of several phylogerontic species of Eurypterus which constitute the end members in different lines of development in North America and mark the decline of the race.

Carbonic. In the Carbonic (Pennsylvanic) are found four species of Eurypterus in Pennsylvania; *Eurypterus* (*Anthraconectes*) *mazonensis* Meek and Worthen (**170**) in the Coal Measures of Mazon Creek, Ill.; two species in the Carbonic of Nebraska, and two doubtful species from St. John, New Brunswick. Particular attention should be called to *Eurypterus* (*Anthraconectes*) *mansfieldi* which C. E. Hall has figured (**98**, pl. IV), showing the form just as it was found lying on ferns in a very perfect state of preservation, in the lower Productive

Coal Measures in Beaver County, Pennsylvania. *Eurypterus stylus* of Hall from the Venango beds is probably the same as *E.* (*Anthraconectes*) *mansfieldi*, both type specimens being compressed longitudinally, but otherwise appearing the same. *Eurypterus* (*Anthraconectes*) *pennsylvanicus* C. E. Hall described from a single small carapace from Pithole City, Venango County, Pennsylvania is probably allied to *E. mansfieldi*, according to Clarke and Ruedemann (**39**, 428). A few fragments called by Hall *E. ? potens* also occur in Pennsylvania. The Carbonic eurypterids are in productive coal beds associated with plants and land animals. The fauna and flora at Mazon Creek have been especially studied by Meek and Worthen (**170**) from whose report the following associates of *Eurypterus mazonensis* are taken:

A Xiphosuran *Euproöps danae* M. and W.
An isopod *Acanthotelson stimpsoni* M. and W.
  also *A. eveni* M. and W.
Decapoda: *Palaeocaris typus* M. and W.
  Anthrapalaemon gracilis M. and W.
Myriopoda: *Euphoberia armigera* M. and W.
Arachnida: *Pulmonia: Eoscorpius carbonarius* M. and W.
  Mazonia woodiana M. and W.
  Architarbus rotundatus Scudder
Cock-roach: *Mylacris anthracophila* Scudder
Other insects: *Miamia danae* Scudder
  Chrestotes lapidae Scudder

The remains from the Coal Measures of Nebraska were found by Barbour in an outcrop one mile south of Peru in the bluffs facing the Missouri River (**10**). The formations exposed there consist of alternating shale and limestone changing rapidly to a shale which finally merges into a massive sandstone. In this last bed there occurred a shaly band composed of thin, irregularly shaly layers, seldom half an inch thick, alternating with micaceous sand. This whole band was scarcely a foot thick and extended for over three hundred feet. Even within the band it was only the topmost two inches of the shale seams which yielded eurypterid remains. These were found in considerable abundance, forty specimens so far having been obtained in an area of as many square feet. The chitinous shells, probably representing merely the shed exoskeletons, have in all cases been reduced to carbonaceous films, but except where these are very thin they are in a good condition of preservation so that the grosser anatomy and surface markings can be seen and even some of the minute sculpturing.

Barbour has described only one species, *Eurypterus* (*Anthraconectes*) *nebraskensis*. It is represented by a large number of individuals and undoubtedly as the beds are worked over a great many more specimens will be obtained. They are for the most part in good condition, though seemingly representing only the exuviæ. The individuals are small, averaging two inches in length, the largest not being even three inches long. Barbour figures and describes, but does not name a second form which he thinks may be a species different from *E. nebraskensis*.

The faunal associates listed by Barbour are: "innumerable leaves, stems and fragments of certain land plants, conspicuously Neuropteris pinnules, stems of Calamites, and leaf-whorls of Asterophyllites . . . . Intimately associated with the eurypterids were considerable amounts of actual plant tissue, preserved as such since Carboniferous times." (**10**, 507–8).

Two species, *Eurypterus ? pulicaris* Salter from the Little River plant bed no. 2 of St. John, New Brunswick, and *Eurypterella ornata* Matthew are so doubtfully identified that Clarke and Ruedemann do not consider even their eurypterid origin as certain. (**39**, 93) The horizon at which they were found was originally supposed to be Devonic, but is now known to be Carbonic.

GREAT BRITAIN

Siluric. *Lower Siluric Llandovery-Wenlock.* The earliest eurypterid remains that have been found anywhere outside of North America, are the fragments of *Pterygotus problematicus* from the May Hill sandstone of upper Llandovery age, found in Eastnor Park near Ledbury, Herefordshire, England. A single chelate appendage was found associated with *Nucula eastnori*, Pentameri and Stricklandiniae. The Mayhill sandstone is a basal one resting by overlap upon various earlier members of the series even upon the Shineton (Dictyonema) shales at Wenlock Edge. There is everywhere a marked break and unconformity between the underlying beds and the May Hill sandstone, indicating that the latter was laid down by an advancing sea, if it was not a terrestrial (fluviatile) sandstone reworked by the sea.

In the Wenlock of the Pentland Hills, Scotland, occurs the first large eurypterid fauna of Europe. The rock containing the eurypterids is "an irregularly fissile, fine-grained sandstone, containing a considerable amount of structureless carbonaceous matter distributed in thin layers" (Laurie, **145,** 151). The only other fossil which Malcolm Laurie found in the rock at the time of his first discovery was *Dictyocaris ramsayi*, but since then Peach and Horne have made a large collection of other types. In 1898 Laurie added some new discoveries from Gutterford Burn, and among these the one specimen of a scorpion, much crushed and lying imbedded in the carbonaceous matter. In the Pentland Hills the Wenlock formation is a yellowish sandstone and conglomerate, showing cross-bedding and in some places ripple marks, and is exposed in several inliers in the Old Red Sandstone, later formations having been eroded. Extensive collections have been made here by Henderson, Brown and Laurie, the latter describing a number of new species. One of the best sections is seen along Gutterford Burn, a tributary of the Esk, where the following specimens have been collected, the determinations having been made by Laurie.

Bembicosoma pomphicus Laurie.
Stylonurus (Drepanopterus) pentlandicus (Laurie).
S. (Drepanopterus) bembicoides (Laurie).
S. (Drepanopterus) lobatus (Laurie).
Eurypterus conicus Laurie.
E. minor Laurie.
Eusarcus scoticus (Laurie).
Eurypterus 3 sp. undet.
Stylonurus elegans Laurie.
S. macrophthalmus Laurie.
S. ornatus Laurie.
Slimonia dubia Laurie.
Dictyocaris ramsayi Salter.
Palaeophonus loudonensis Laurie.

Upper Siluric or Ludlow. The Ludlow of England has yielded eight species of eurypterids all in a most fragmentary condition, making it difficult to determine forms accurately. They all come from the Ludlow outcrops in Shropshire and Herefordshire. From the Aymestry limestone there are some remains which have been doubtfully referred to *Pterygotus problematicus.* This same species appears again and again throughout the remainder of the Siluric, being rare in the Upper Ludlow group, but becoming more common towards the top of the Temeside group in the Ludlow district. *Eurypterus acuminatus* Salt. and *E. linearis* are rare in the Upper Ludlow, the former occurring also in the Temeside group. *Eurypterus pygmæus* Salt. and *Stylonurus megalops* Salt. are common as fragments in the higher olive shales of the Temeside group. *Pterygotus banksii* Salt. together with numerous indeterminable species of Eurypterus are found in the Ludlow Bone-Bed; this species is also common in the Platyschisma bed and the upper olive shales of the Temeside group; in the same shale *P. ludensis* Salt. is abundant. In all cases where species are reported to be common it is to be remembered that no entire specimens are found but only fragments and *disjecta membra*. The occurrences cited are from the Ludlow district in Shropshire; to the southwest in the Downton Castle sandstone at Kington in Herefordshire *Pterygotus banksii* has been found in large numbers associated with *P. gigas*, the spines of crustacea and fish and also *Platyschisma helicites* and *Lingula cornea*. Salter has further described *Eurypterus abbreviatus* from a single telson which he found at Kington. Brodie collected specimens of *Pterygotus banksii*, *Eurypterus pygmaeus*, *E. acuminatus*, and *E. abbreviatus* at Purton, Herefordshire. The greatest abundance of specimens is found in a sandy marl lying just below a yellow sandstone containing plants, seed-vessels of Lycopodiaceae and fragments of eurypterids. The horizon is about that of the Ludlow Bone-Bed (**24**, 236).

The Ludlow of Scotland is found only in a few inliers in Lanarkshire. Division 3 recognized by Peach and Horne (**215**) consists of flagstone and greywackes with Ceratiocaris beds and containing the Ludlow fish band. From these beds *Slimonia acuminata* Salter has been described associated with five species of Ceratiocaris and worm tracks. From the same shales *Pterygotus bilobus* Salter and the common Ludlow fish *Thelodus scoticus* are reported. In certain places occur *Beyrichia kloedeni* and *Platyschisma helicites* forms very frequently associated with Upper Siluric eurypterids. The fish band contains *Slimonia acuminata*, the myriopod *Archidesmus loganensis* Peach, four species of the phyllocarid crustacean Ceratiocaris and one of Physocaris, together with numerous fish fragments and two species of Thelodus. Of great interest has been the discovery by Peach in this fish band of one of the oldest scorpions from Great Britain, *Palaeophonus caledonicus* Hunter. This is approximately the same horizon at which Lindström found *Palaeophonus nuncius* in Gotland (see below, p. 34). The eurypterid horizon par excellence occurs in the next higher division above the fish band and contains *Eurypterus lanceolatus* (Salt.), *Eusarcus obesus* (Woodw.), *E. scorpioides* (Woodw.), *Pterygotus bilobus* Salt., together with three varieties of this species, *P. raniceps* (Woodw.), *Slimonia acuminata* (Salt.) and *Stylonurus logani* (Woodw.). The Pterygotus beds are followed by the "Trochus," more properly, Platyschisma beds which correspond to the beds of the same name in England, and which contain fragments of *Slimonia acuminata* as do the next overlying beds which mark the transition into the sandy Lanarkian series.

The Lanarkian. About 1400 to 1500 feet above the base of this series occurs a fish-band in the carbonaceous shales of which *Eurypterus dolichoschelus* (Laurie) has been found associated with Ceratiocaris, five species of fishes, and Pachytheca and Parka. At another locality seven species of fishes, Ceratiocaris, Dictyocaris, Pachytheca, a Myriopod and *Eurypterus dolichoschelus* (Laurie) and *Stylonurus ornatus* (Laurie) have been found.

DEVONIC. The Devonic formations of Great Britain have a better representation of eurypterids than have those of North America. The Old Red Sandstone of Forfarshire has yielded *Pterygotus anglicus* in abundance and in a good state of preservation and one nearly entire specimen of *P. minor.* From the same region come three species of *Stylonurus*, *S. scoticus*, *S. powriei*, *S. ensiformis*, and finally the little known *Eurypterus brewsteri.* In the Old Red Sandstones of England occur *Eurypterus pygmaeus and Stylonurus symondsii.* Fragments of *Pterygotus problematicus* have been reported from the Lower Old Red of the Ludlow district. A few fragments of *Eurypterus hibernicus* Baily have been found in the Upper Old Red of Kiltorcan, Kilkenny County, Ireland. There are thus ten species of eurypterids from the Devonic of Great Britain, all occurring in the Old Red Sandstone facies of deposits associated with fishes, land plants, fluviatile molluscs, myriopods and crustacea, such as the fresh or brackish-water phyllopod, Estheria, the ostracod Beyrichia and certain phyllocarids. With the exception of *Pterygotus anglicus* none of the eurypterids is either abundant or well preserved, most of the species being represented by a single portion of the exoskeleton or by a number of fragments. Moreover, these fragments are scattered in occurrence geologically and geographically. Six species are found in Forfarshire, Scotland, in the Lower Devonic (Caledonian); three species are sparingly represented in Brecknockshire and Herefordshire, England, at the same horizon; while a few fragments of a single species occur in the Upper Old Red of Ireland.

MISSISSIPPIC OR CALCIFEROUS. The Calciferous fresh-water limestone of Scotland, equivalent in age to the Mississippic of North America, has yielded three species of Eurypterus: *scabrosus*, Woodward, *scouleri* Hibbert and ? *stevensoni* Ethridge. Of the first species a doubtful fragment has been reported from Eskdale, Scotland. Hibbert was the first to describe as a Eurypterus the two nearly complete individuals and three or four fragments found in the Burdiehouse fresh-water limestone at Kirkton, near Bathgate, West Lothian. The organic remains are scattered through in no regular order and are not confined to the limestone particularly, but occur in the sandy beds above and below, not in particular seams. One of the eurypterid remains had earlier been described under the name *Eidothea*, but Hibbert rightfully called it *Eurypterus scouleri* (**116**, 280, 281, pl. XII). Vegetal matter is diffused through the limestone and in this fossil plants are well preserved, the form particularly abundant being *Sphenopteris affinis*. Microscopic Entomostraca abound which have been named by Hibbert *Cypris scoto-burdigalensis*, and a microscopic mollusc approaching Planorbis also occurs. Fish remains are abundant: *Gyracanthus formosus* Agassiz, ganoid and sauroid teeth, and many coprolites are found. Woodward says of this limestone: "it is a fresh water deposit, and abounds in bands of silex alternating with calcareous matter and presents all the appearance of having been deposited by thermal waters during the Carboniferous epoch" (**312**, 180). The third species above referred to was described by Etheridge from a few fragmentary spines found in a light-colored micaceous sandstone of the Cement-stone group in Kimmerghame quarry, near Dunse in Berwickshire, Scotland. In the same shire Peach has recently discovered some fragments for which he erected the genus Glyptoscorpius, a eurypterid which had combs, and walking feet ending in two claws. In the Calciferous sandstone here at Lennel Braes, near Coldstream, Berwickshire, a specimen of *G. perornatus* Peach showing five body segments much broken, and a number of combs, referred to *G. caledonicus* (Salter) have been found. Besides these, are a number of fragments referred to the genus Glyptoscorpius, but specifically unidentifiable (**209**, 516–525). At the River Esk, four miles south of Langholm, Dumfriesshire, the two species of Glyptoscorpius are found with the following associates: several species of Phyllocarida, *Ceratiocaris scorpioides* Peach, *C. elongatus* Peach; Peracarida, *Anthrapalaemon etheridgei* Peach, *A. parki* Peach, *A. traquairii* Peach, *A. macconochii*, *A. formosus* Peach, *Palaeocrangon eskdalensis* Peach, *Palaeocaris scoticus* Peach, and later discoveries have added *Pseudo-Galathea rotundata* and *Palaeocrangon elegans*. At Tweeden Burn, Liddesdale, have been found many *membra disiecta*, unidentifiable. The fauna also includes some Xiphosurans: *Prestwichia alternata* Peach from Lavuston Burn, upper Liddesdale, *Prestwichia rotundata* Woodward from the River Esk locality and *Cyclus testudo* Peach from Langholm. Many of these crustacean forms are quite well preserved. Scorpions also occur at Langholm: *Eoscorpius glaber* Peach, *E. euglyptus* Peach and *E. inflatus* Peach. These forms though never perfect are very complete and show all parts well.

CARBONIC OR CARBONIFEROUS. In the Coal Measures of Great Britain the final stragglers among the eurypterids are found, just as they are in North America. *Eurypterus* (*Arthropleura*) *mammatus* Salter includes fragments from Pendleton Colliery, near Manchester, England, which are associated with many plant remains, a few of which may be mentioned:

Lepidodendron obovatum.
Lepidodendron sternbergii.
Lepidodendron elegans.
Neuropteris loshii.
Neuropteris heterophylla.
Neuropteris gigantea.
Cyclopteris flabellata.
Sphenopteris obtusiloba.
Sphenopteris latifolia.
and some others

BOHEMIA

SILURIC. *Lower Siluric* Ee_1, Ee_2 *of Barrande*. From the Siluric basin of Bohemia Barrande listed six species of Pterygotus, all of which are represented by the merest fragments and are of rare occurrence. They are found in undoubted marine formations, for Ee_1 is a black graptolite-bearing shale, while Ee_2 contains numerous cephalopods, gastropods, trilobites and corals (**12**, 39–44). The species of Pterygotus are: *bohemicus, comes, cyrtochela, kopaninensis, mediocris and nobilis*. Of the general preservation and faunal associates of these eurypterids Barrande remarks:

"Our basin, so privileged in respect to the frequency and the state of preservation of the trilobites and the other crustacea, appears, on the contrary, very poor in the fossils representing the two types of eurypterids, which are recognized in our formations. (Pterygotus and Eurypterus).

". . . . Far from finding individuals complete and well preserved, it will prove difficult to add any new facts of importance to those already published on the organization of the species of this type.

"That advantage is not reserved for us, for the Silurian basin of Bohemia, so favored in all other respects, is relatively poor in fossils of the genus Pterygotus, not only because of their great rarity, but also because of the reduction of the specimens to little fragments. Since almost all of the remains are found in the large horizon of the Cephalopods, that is, in our limestone band e 2, it seems to us that one may attribute the almost total disappearance of these gigantic Crustacea to the voracity of these molluscs, against whom they were forced to maintain the struggle for existence." (**13**, 556).

We need not consider seriously this interpretation of the fragmental character of the eurypterid remains as they can be interpreted in another manner (see p. 199).

Semper (**261**) has recently done some work in the region and has revised and added to Barrande's original species. In e_1 β at Podol Dvorce, near Prague, he has collected a few fragments to which he has given the name *Pterygotus barrandei* of which there are also some fragments at Dlouhá hora, in horizon e_2. A few endognathites from the former locality have been described as *P. beraunensis* Semper, since they come from near Beraun. Some fragments of a swimming foot are also described by Semper from e_2, as *P. blahai*, in a thinly laminated limestone rich in Orthoceras which occurs at Višňovka near Lochhov. Of all the species found in Bohemia the best one is a fragmentary individual showing the head with the first eight somites attached, and a few separate fragments, these constituting the species *Eurypterus acrocephalus* Semper from horizon e_1, at Dvorce. From these various occurrences it is apparent that the eurypterids, though represented by a large number of species in the beds of Wenlock or Niagaran age of Bohemia, are found only rarely and in a most fragmentary condition, although the large marine fauna occurring in the same horizon is one of the largest and most perfect that is known, forming the basis for Barrande's ponderous work on the *Système Silurienne* in which many volumes are devoted to the description and figuring of the marine fossils, while a very little space suffices for the meagre eurypterid fauna. Barrande notices in a paper on the correlation of the Siluric deposits of Bohemia and Scandinavia (*Parallele entre les Depôts Siluriens de Bohême et de Scandinavie* (**11**), that Pterygotus remains have been found at Klinta in Scania, southern Sweden, which recall *Pterygotus problematicus* of England (**11**, 58)

Upper Siluric or Ff_1 *of Barrande.* Two species of Eurypterus have been recorded from the Upper Siluric of Bohemia in the same incomplete condition that those from the Lower were found in. *E. pugio* Barrande and a species related to *P. bohemicus* Barrande are the only representatives in this period. The latter is reported by Semper from a single claw and part of an abdomen found at Cerná rockle, Kosoř in a black limestone of Ff_1 age.

CARBONIC. *Coal Measures of Bohemia.* In a rather blackish grey shale at Wilkischen, near Pilsen, Reuss found two macerated, but nearly complete individuals and a cephalon of a eurypterid which he named *Eurypterus imhofi*, and which is associated on the same slab with pinnules of Pecopteris. Reuss says that this fossil "of the Bohemian Coal Measures—a freshwater formation— is without doubt derived from a freshwater or brackish water ancestor (**228**, 83)."

BELGIUM

DEVONIC. *Upper Devonic.* In only one locality in Belgium have eurypterids been found. Some thirty kilometers southwest of Liege at Pont de Bonne near Modave is exposed a section showing the Upper Devonic sandstones of Condroz. Lohest, Braconier and Destinez in working up this section found a few eurypterid fragments in 1888 and in the following year these were described by Julien Fraipont and Maximin Lohest. *Eurypterus lohesti* was described by Dewalque from two specimens, one the counterpart of the other, representing a complete cephalon. Fraipont described *Eurypterus ? dewalquei* from a cephalon, a portion of an abdominal segment, and a few other fragments. One other fragment, a portion of one of the appendages, is thought by Fraipont to belong to a species related to *E. ? dewalquei*, but because of the similarity in ornamentation and agreement in size, he makes it only a variety, calling it *E. ? dewalquei var. longimanus.*

The beds in which these remains were found are described by Lohest as follows (**68**, 55):

"We procured the major part of our fossils from the bed of green shales. They contain: *Glyptolepis multistriatus, G. radians, Holop-*

tychius dewalquei, Eurypterus, Spirorbis. Mr. Destinez found a beautiful Ichthyolite which is probably new. We cite again: lamellibranchs, lingulas, ferns and Lepidodendron. That bed contains sometimes thin layers of sandstones, on which one finds associated on the same planes of stratification lingulas, lamellibranchs, ferns, and ganoid scales. Mr. I. Braconier has collected excellent specimens which demonstrate the certainty of this fact.[6] . . . .

"In beds F, G, H, I, we have not collected any determinable fossils; but in the lower part of bed J we have found vegetal matter, scales of the fish, *Holoptychius inflexus*, a small species of Pterichthys and the remains of a Dipterus as I have pointed out." (Fraipont, **68**, 55).

A little lower in the series in bed B impressions have been found which suggest those of rain-drops, also very numerous axes of vegetal matter probably, as suggested by Mr. Mourlon, stipes of the fern *Palaeopteris hibernica*, and in the same bed Mr. Destinez found a large bone, belonging apparently to a fish.

BALTIC ISLES AND RUSSIA

SILURIC. *Upper Siluric of Gotland.* The Baltic Isles have long been famous for their Siluric sections which are so excellently shown on Gotland. The lowest eurypterid horizon is found in the *Pterygotus marl* of Gotland of Upper Siluric age. Although the sections in the northern and southern parts of the island have been studied separately and the correlations are not as yet complete, still one important fact has stood out for the whole island: there is everywhere a great break between the Lower and Upper Gotlandian (Siluric), indicating in many places that there was at this time a retreat and a subsequent advance of the sea. In the north around Visby, Hedström (**113**) has recognized seven subdivisions of the Gotlandian. Beginning at the base, the first bed to be shown along the shore is the Stricklandia marl (I of Hedström), with Palæocyclus as the characteristic fossil. Then follows II, a marly limestone showing reef masses at intervals and containing a Niagaran fauna. The succeeding beds (III) are of particular interest to us. At the base are 3 meters of yellowish grey limestone with crinoids, and then follow 16 meters of grey marls interstratified with limestone, the upper 5 meters of which consist of stratified limestones, oolitic at the base, but becoming gradually coarser towards the top where they are conglomeratic, and where ripple-mark structures are sometimes observable. Above these strata comes a complex of layers, one meter thick, consisting of marl shales and limestones with *Pterygotus osiliensis* and *Palæophonus nuncius*, a scorpion. Lindström has called this thin stratum the *Pterygotus marl*, and it is seen to lie just at the top of III.[7] Here there is a break and disconformity, above which follows a conglomerate (IV) with waterworn gastropoda and portions of *Spongiostroma holmi* Rothpletz. The relations of the reef limestone and marl are well shown in the vicinity of Visby. The reefs are composed of non-stratified accumulations of Stromatoporæ mainly, with a few corals in addition. Between the reefs of II are the finely stratified bituminous, brownish shales of III, well shown on the island of Karlsö west of Visby, which contain a marine and estuarine fauna mixed.

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[6] M. I. Braconier a recueilli de superbes échantillons qui demontrent ce fait a l'évidence."

Upper Siluric of Oesel. This island has yielded a large crustacean fauna in the usual association with eurypterids. Two species of Eurypterus are reported: *E. laticeps* Schmidt from two fairly perfect head shields, and *E. fischeri* Eichwald from many excellent specimens. There is also an abundance of fragments of *Pterygotus osiliensis.* The bed in which these occur is a fine grained Platten-kalk or dolomite, with a peculiar fauna throughout; this is followed by other granular limestones containing the usual uppermost Siluric fauna. The Eurypterus beds have a fairly wide extent in western Oesel, but the fullest development of the fauna is seen only near Rootziküll, on the west coast of the island, in the parish of Kielkond. Here the beds are a dolomite in which the chitinous exoskeletons of Pterygotus and Eurypterus have been excellently preserved, and even the tail sting of a Ceratiocaris and the shields of two cephalaspid fishes, *Thyestes verrucosus* Eichw. and *Tremataspis schrenckii* Schmidt, and the shells of the little *Lingula nana* Eichw. have been found. Rather rarely occurring are the Hemiaspidae: *Bunodes lunula* Eichw.; *B. rugosus* Nieszk. and *schrenckii* Nieszk. sp. as well as *Pseudoniscus aculeatus* Nieszk. and the shells of *Orthoceras tenue* Eichw. Bunodes and Leperditia are represented by many specimens, but these and all the other fossils mentioned show, in place of the shell which is destroyed, only a black carbonaceous film representing the organic material (Schmidt **248,** 28). The eurypterids do not show the same kind of preservation, for Schrenck (**254**, 35) reports the integuments of *Eurypterus remipes* Dekay (with which *E. tetragonophthalmus* Fischer is synonymous and which Schmidt has since placed under *E. fischeri*,) to be entirely unaltered, not only chemically, still remaining pure chitin, but also in their entire internal make-up and with their original color such as is characteristic of living representatives.

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[7] Professor Grabau has argued that this bed should be placed in the Upper Gotlandian.

AUSTRO-RUSSIAN BORDER LANDS

SILURIC. *Upper Siluric of Podolia and Galicia.* From various localities, mainly in Galicia, Austria, but occasionally from Podolia, Russia, a few fragments of *Eurypterus fischeri* are reported, together with specimens determined with difficulty to be *Pterygotus osiliensis*, and also three telsons of specifically unidentifiable Stylonurus.

DEVONIC. *Middle Devonic of Galicia.* A single telson of a Pterygotus species has been found by Siemiradzki in the Devonic coral limestone of Skala, Valencia (**263**).

AUSTRALIA

SILURIC. *Upper Siluric.* Professor McCoy has reported (**168**) the finding by Mr. F. Spry of four eurypterid remains in the Upper Silurian rocks underlying Melbourne. These rocks have been correlated by McCoy with the Victorian series. The matrix in which the merostome fragments were found is described as resembling very closely the black flaggy layers of the uppermost Ludlow of Lesmahagow, Scotland, while the eurypterid found there seems to have its closest affinities to *Pterygotus bilobus*. The specimen figured is fragmentary, but apparently of a eurypterid, which McCoy has referred to *Pterygotus australis*.

GERMANY

CARBONIC. *Middle Saarbrücker.* In the Saarbrücken "basin" of Germany the Carbonic has been divided into two parts, the upper or Ottweiler with grey and red sandstone at the top and grey shale and sandstone below containing *Pecopteris arborensis*, Estheria, *Leaia baentschiana* and fish remains; and the lower or coal-bearing Saarbrücken beds containing in their middle members abundant plant remains and two eurypterid species. *Arthropleura armata* Jordan is represented by two or three abdominal segments found in the beds in the Friedrichsthal tunnel two miles from Saarbrücken, where in the same beds are plant remains of *Lepidophyllum lineare* Brong., and *Anthracosaurus raniceps*, *Dictyoneura blattina* and other insects. In the railroad shaft at Jägersfreude, $\frac{3}{4}$ of a mile from Saarbrücken, one incomplete individual of a form called by Jordan *Adelopthalmus* (*Eurypterus*) *granosus* has been found (**135**).

SOUTH AMERICA

Carbonic. *Coal Measures of Brazil.* David White described some fragments from the Santa Catharina system, about 55 meters above the granite floor (Tubarão series) or 225 meters below the Iraty black shale (Passa Dois series) northeast of Minas, Santa Catharina, Brazil (**297,** 229, 589, 605). The fragments are of most doubtful identification, some being apparently plant remains, but others having a suggestion of relation to the Eurypterida (**297,** pl. XI, figs. 4, 6, 7, 8). These are described as *Hastimima whitei* White.

AFRICA

Devonic. *Witteberg series.* From the Upper Devonic Witteberg series of Cape Colony, South Africa, Professor A. C. Seward has described two fragments of a fossil which he considers to be a eurypterid. He compared it with the species described by David White from Brazil and called it Hastimima sp., saying: "The view which seems to me most hopeful is that this fossil represents part of a body-segment of a Eurypterid" (**262,** 485). Seward sent the specimens to Woodward who not only concurred in the opinion as to the eurypterid nature of the remains, but he also considers that the Brazilian forms are eurypterids (**325,** 486). It is gratifying to note that the opinion expressed by these earlier writers is fully supported by Clarke and Ruedemann in their monograph where they have discussed this genus (**39,** 400–406) and figured some more of the fragments from Brazil.

The Witteberg series consists of a hard blue micaceous quartzite, replaced in some localities by shale or slate. So far as known it is unfossiliferous except for occasional plant stems allied to Lepidodendron and the widespread markings known as *Spirophyton caudagalli.* A photograph of this fossil given by Hatch and Corstorphine in their *Geology of South Africa* (**111,** fig. 22.) reveals no essential difference between it and the *Spirophyton caudagalli* of the Esopus, Oriskany and Hamilton of eastern North America. Seward considers that it is an inorganic structure and Grabau has gone even further in suggesting that it is due to the blowing back and forth of reed-like plants on a plastic surface capable of holding such markings long enough until covered over by wind-blown dust or sand. At any rate, the formation is undoubtedly non-marine, and the two eurypterid fragments therein could hardly have come from any other source than the land waters.

TABLE I

Geological and Geographical Distribution of the Eurypterida Throughout the World

PALÆOZOIC ARACHNIDA OF THE SUBCLASS: MEROSTOMATA (DANA) WOODWARD ORDER: EURYPTERIDA BURMEISTER FAMILY: EURYPTERIDÆ BURMEISTER	UNITED STATES	CANADA	ENGLAND	SCOTLAND	IRELAND	GERMANY	BELGIUM	BOHEMIA	ISLAND OF OESEL	ISLAND OF GOTLAND	SWEDEN	GALICIA, AUSTRIA-HUNGARY	PODOLIA, RUSSIA	AUSTRALIA	SOUTH AMERICA	AFRICA	PORTUGAL	PRECAMBRIC		U. CAMBRIC	ORDOVICIC				SILURIC																																									DEVONIC																MISSISSIPPIC				CARBONIC								PERMIC
																					M.	Upper			Lower and Middle													Upper																																																									
																																												Upper Ludlow Group				Temeside Group																							Old Red Sandstone, Scotland																								
																																																Downton Castle		Temeside shales																																													
																		Belt Terrane	Altyn limestone	Potosi limestone	Normanskill sh. and ss.	Schenectady shale	Utica shale	Liberty limestone	Tuscarora	Clinton sandstone	Eramosa beds	Guelph dolomite	Shales in Shawangunk grit	Keefer sandstone	Pittsford shale	Farmer's Mills shales	May Hill ss. and Tarannon sh. and ss.	Lower Ludlow	Wenlock	Kuchelbader sh. E e_1	Budňaner ls. E e_2	Put-in-Bay dolomite	Bertie waterlime	Rondout waterlime	Manlius limestone	Kokomo waterlime	Knoydart formation	Rhynchonella-nucula beds	Chonetes beds	Spirifer-elevata beds	Ludlow bone-bed	Platyschisma bed	Massive sandstone	Rubbly shales	Olive shales	Temeside bone-bed	Transition beds to Old Red of Eng.	Ledbury shales	Ceratiocaris beds, div. 3, Peach and Horne	Pterygotus beds, div. 4, Peach and Horne	Trochus beds, div. 5, Peach and Horne	Upper Ludlow, div. 6, Peach and Horne	Lanarkian, div. 9, Peach and Horne	Pterygotus marl	Zone K, waterlime of Oesel	Öved-Ramsåsa ls. zone 1	Lochkover ls. Ff.	Victorian series of Australia	Upper Siluric of Podolia	Transition beds to Dev., Galicia	Portage sandstone	Chemung sandstone	Catskill sandstone	Campbellton beds	Tealing beds	Pterygotus beds of Carmylie	Cephalaspis beds	Turin Hill beds	Abroath flagstones	Edgell shales	Old Red of Lorne	Cornstones, M. Old Red, Eng.	Devonic of Podolia	Famennian ss. of Condroz	Kiltorcan sandstone	Witteberg shales	Waverly	Calciferous shale and sandstone	Cement-stone group	Burdie House ls	Coal Measures (Alleghany)	Arenaceous sh. in Coal Measures	Sh. below Darlington coal	Coal Measures of Nebraska	Coal Measures of England	Coal Measures of Germany	Santa Catharina system	Coal Measures of Bohemia	Rot liegende of Portugal
	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
I. Genus Beltina Walcott																																																																																															
1. B. danai Walcott	×	×																×	×																																																																												
II. Genus Bembicosoma Laurie																																																																																															
2. B. pomphicus Laurie				×																															×																																																												
III. Genus Dolichopterus Hall																																																																																															
3. D. breviceps Cl. and R.	×																				×																																																																										
4. D. frankfortensis Cl. and R.	×																					×																																																																									
5. D. laticeps (Schmidt)									×																																																				×																																		
6. D. latifrons Cl. and R.	×																					×																																																																									
7. D. machrochirus Hall	×																																						×																																																								
8. D. otisius Clarke	×																												×																																																																		
9. D. siluriceps Cl. and R.	×																																						×																																																								
10. D. stylonuroides Cl. and R.	×																												×																																																																		
11. D. (?) testudineus Cl. and R.	×																																						×																																																								
IV. Genus Echinognathus Walcott																																																																																															
12. E. clevelandi Walcott	×																						×																																																																								
V. Genus Eurypterus Dekay																																																																																															
13. E. abbreviatus Salter			×																																														×																																														
14. E. accuminatus Salter			×																																						×					×																																												
15. E. approximatus Hall and Clarke	×																																																																																		×												
16. E. brewsteri H. Woodw.				×																																																																							×																				
17. E. brodiei H. Woodw.			×																																														×																																														
18. E. cephalaspis Salter			×																																														×																																														
19. E. chadwicki Cl. and R.	×																				×																																																																										
20. E. conicus Laurie				×																															×																																																												
21. E. cyclophthalmus Laurie				×																															×																																																												
22. E. dekayi Hall	×																																						×																																																								
23. E. ? dewalquei Fraipont							×																																																																									×															
24. E. ? dewalquei var. longimanus Fraipont							×																																																																									×															
25. E. dolichoschelus Laurie				×																																																			×				×																																				
26. E. douvillei de Lima																	×																																																																														×
27. E. fischeri Eichwald									×				×																																																×				×																														
28. E. fischeri Eichwald var. rectangularis Schmidt									×																																																				×																																		
29. E. hibernicus (Baily)					×																																																																												×														
30. E. imhofi Ruess								×																																																																																						×	
31. E. lacustris Harlan	×	×																																					×																																																								
32. E. lacustris Hall var. pachychirus Hall	×																																																																																														
33. E. lanceolatus Salter				×																																																				×																																							
34. E. linearis Salter			×																																											×																																																	
35. E. lohesti Dewalque							×																																																																									×															
36. E. maria Clarke	×																								×				×																																																																		
37. E. microphthalmus Hall	×																																					×			×																																																						
38. E. minor Laurie				×																															×																																																												
39. E. moyseyi H. Woodw.			×																																																																																								×				
40. E. pittsfordensis Sarle	×																														×																																																																
41. E. pristinus Cl. and R.	×																					×																																																																									
42. E. (?) (Dolichopterus?) prominens Hall	×																									×																																																																					
43. E. pustulosus Hall	×																																						×																																																								
44. E. pygmaeus Salter			×																																														×		×																																												
45. E. ranilarva Cl. and R.	×																																									×																																																					
46. E. remipes Dekay	×																																						×	×																																																							
47. E. ruedemanni O'Connell	×																					×																																																																									
48. E. scouleri Hibbert				×																																																																													×					×									
49. E. cf. scouleri Hibbert (Roemer)						×																																																																																						×			
50. E. ? (Dolichopterus?) stellatus Cl. and R.	×																					×																																																																									
51. E. ? stevensoni Etheridge				×																																																																																	×										
52. E. wilsoni H. Woodw.			×																																														×																																														
53. E. sp. Barbour	×																																																																																														
54. E. sp. Elles and Slater			×																																										×		×		×	×																																													
55. E. sp. Peach and Horne				×																															×																																																												
56. E. sp. Laurie				×																															×																																																												
57. E. sp. (?) Laurie				×																															×																																																												
58. E. sp. Moberg											×																																																			×																																	
59. E. (Adelopthalmus) granosus Jordan						×																																																																																						×			
60. E. (Anthraconectes) mansfieldi C. E. Hall	×																																																																																								×						
61. E. (Anthraconectes) mazonensis Meek & Worthen	×																																																																																						×								
62. E. (Anthraconectes) nebraskensis Barbour	×																																																																																									×					
63. E. (Anthraconectes) pennsylvanicus C. E. Hall	×																																																																																							×							
64. E. (Onychopterus) kokomoensis Miller and Gurley	×																																									×																																																					
65. E. (Tylopterus) boylei Whiteaves		×																										×																																																																			
VI. Genus Eusarcus Grote and Pitt																																																																																															
66. E. acrocephalus (Semper)								×																												×																																																											
67. E. (?) cicerops Clarke	×																												×																																																																		
68. E. linguatus Cl. and R.	×																				×																																																																										
69. E. logani M. Y. Williams		×																									×																																																																				
70. E. (?) longiceps Cl. and R.	×																					×																																																																									
71. E. newlini (Claypole)	×																																									×																																																					
72. ? E. obesus H. Woodw.				×																																																					×																																						
73. E. punctatus (Salter)			×																															×	×																																																												
74. E. aff. punctatus (Woodw.) et acrocephalus (Semper) (Seeman)								×																												×																																																											
75. E. raniceps (H. Woodw.)				×																																																			×																																								
76. E. scorpioides (H. Woodw.)				×																																																			×																																								
77. E. scorpionis Grote and Pitt	×																																						×																																																								
78. E. scoticus (Laurie)				×																															×																																																												
79. E. simonsoni (Schmidt)									×																																																				×																																		
80. E. triangulatus Cl. and R.	×																					×																																																																									
81. E. vaningeni Cl. and R.	×																															×																																																															
VII. Genus Glyptoscorpius Peach																																																																																															
82. G. caledonicus (Salter)				×																																																																																×											
83. G. perornatus Peach				×																																																																																×											
VIII. Genus Hastimima D. White																																																																																															
84. H. whitei, White															×																																																																														×		
85. H. sp. Seward																×																																																																		×													
IX. Genus Hughmilleria Sarle																																																																																															
86. H. magna Cl. and R.	×																					×																																																																									
87. H. shawangunk Clarke	×																								×				×																																																																		
88. H. socialis Sarle	×																														×																																																																
89. H. socialis var. robusta Sarle	×																														×																																																																
90. H. cf. socialis	×																													×																																																																	
X. Genus Megalograptus S. A. Miller																																																																																															
91. M. welchi S. A. Miller	×																							×																																																																							
XI. Genus Strabops Beecher																																																																																															
92. S. thacheri Beecher	×																			×																																																																											
XII. Genus Pterygotus Agassiz																																																																																															
93. P. anglicus Agassiz				×																																																																			×	×	?	×	×		×																		
94. P. arcuatus Salter			×																															×																																																													
95. P. altanticus Cl. and R.		×																																																																				×																									
96. P. australis McCoy														×																																																		×																															
97. P. barrandei Semper								×																												×	×																																																										
98. P. beraumensis Semper								×																												×																																																											
99. P. bilobus Salter var. acidens Woodw.				×																																																			×	×																																							
100. P. bilobus var. crassus Salter																																																							×	×																																							
101. P. bilobus Salter var. inornatus Woodw.				×																																																			×	×																																							
102. P. bilobus var. perornatus (Salter)				×																																																			×	×																																							
103. P. blahai Semper								×																													×																																																										
104. P. bohemicus Barrande								×																												×	×																																																										
105. P. aff. bohemicus Barrande (Seemann)								×																																																							×																																
106. P. buffaloensis (Pohlman) emend. Cl. and R.	×																																						×																																																								
107. P. cobbi Hall	×																																						×																																																								
108. P. cobbi Hall var. juvenis Cl. and R.	×																																						×																																																								
109. P. fissus Seemann								×																													×																																																										
110. P. gigas Salter			×																																														×		×	×																																											
111. P. kopaninensis Barrande								×																													×																																																										
112. P. ludensis Salter			×																																														×		×	×	×																																										
113. P. macrophthalmus Hall	×																																						×																																																								
114. P. minor H. Woodw.				×																																																																								×																			
115. P. monroensis Sarle	×																														×																																																																
116. P. (Eusarcus ?) nasutus Cl. and R.	×																				×	×																																																																									
117. P. nobilis Barrande								×																												×	×																																																										
118. P. normanskillensis Cl. and R.	×																				×																																																																										
119. P. problematicus Salter			×																														×															×	×		×	×																																											
120. P. cf. problematicus Salter (Seemann)								×																													×							×																																																			
121. P. prolificus Cl. and R.	×																					×																																																																									
122. P. ? stylops Salter			×																																														×																																														
123. P. taurinus Salter			×																																																			×																																									
124. P. sp. (Siemiradzki)								×																																																																							×																
125. P. sp. (H. Woodw.)		×																																																																																													
126. P. (Erettopterus) banksii Salter			×																																												×	×	×		×																																												
127. P. (Erettopterus) globiceps Cl. and R.	×																								×				×																																																																		
128. P. (Erettopterus) cf. globiceps Cl. and R.	×																												×														×																																																				
129. P. (Erettopterus) grandis (Pohlman) emend. Cl. and R.	×																																						×																																																								
130. P. (Erettopterus) osiliensis Schmidt emend O'Connell									×	×		×																																																×	×					×																													
XIII. Genus Slimonia Page																																																																																															
131. S. acuminata (Salter)				×																																																			×	×	×	×																																					
132. S. cf. acuminata (Salter) (Seemann)								×																													×																																																										
133. S. dubia Laurie				×																															×																																																												
XIV. Genus Stylonurus Page																																																																																															
134. S. beecheri Hall	×																																																																			×																											
135. S. ensiformis H. Woodw.				×																																																																						×																					
136. S. ? limbatus Cl. and R.	×																					×																																																																									
137. S. logani H. Woodw.				×																																																				×																																							
138. S. macrophthalmus Laurie				×																															×																																																												
139. S. megalops (Salter)			×																																																×																																												
140. S. modestus Cl. and R.	×																				×																																																																										
141. S. myops Clarke	×																												×																																																																		
142. S. ornatus Laurie				×																															×																																																												
143. S. powriei H. Woodw.				×																																																																						×																					
144. S. symondsii (Salter)			×																																																																											×																	
145. S. (?) scabrosus (H. Woodw.)			×																																																																																	×											
146. S. ? wrightianus (Dawson)	×																																																																		×																												
147. S. (Ctenopterus) cestrotus Clarke	×																												×																																																																		
148. S. (Ctenopterus) elegans Laurie				×																															×																																																												
149. S. (Ctenopterus) excelsior Hall	×																																																																				×																										
150. S. (Ctenopterus) multispinosus Cl. and R.	×																														×																																																																
151. S. (Drepanopterus) bembicoides (Laurie)				×																															×																																																												
152. S. (Drepanopterus) lobatus (Laurie)				×																															×																																																												
153. S. (Drepanopterus) longicaudatus Cl. and R.	×																																									×																																																					
154. S. (Drepanopterus) pentlandicus Laurie				×																															×																																																												
155. S. (Tarsopterus) scoticus (H. Woodw.)				×																																																																						?																					
156. S. sp. α Cl. and R.	×																												×																																																																		
157. S. sp. β Cl. and R.	×																												×																																																																		
158. S. sp. γ Cl. and R.	×																												×																																																																		
159. S. sp. δ Cl. and R.	×																												×																																																																		

PORTUGAL

PERMIC. About a third of the way south from Porto to Lisbon and about 40 km. in from the coast lies Bussaco, famous for its Carboniferous rocks and the abundant flora therein. This region was studied as long ago as 1850 by Carlos Ribeiro. Three years later a symposium on the sections and fossils of Bussaco appeared in the *Quarterly Journal of the Geological Society of London*, and then in 1890 Wenceslau de Lima made a very complete study of the region, with the result that, after a careful identification of the flora, he was able to show that certain of the beds are Permic in age, belonging to the lower Rothliegende. During his investigations he found a single small eurypterid, the cephalon, body segments and telson intact, though all of the appendages are missing. The animal measures 32.5 mm. in length, has a large cephalon, a bulging body made up of seven somites and a long tail formed by the last seven segments. To this form he gave the name *Eurypterus douvillei.* Associated with this eurypterid are the plants *Walchia piniformis* and *Sphenophyllum thoni.* The beds in which these fossils are found are a series of shales, sandstones and conglomerates from the abundance of which de Lima argues that torrential conditions must have obtained at the end of the Carbonic and beginning of the Permic (**149**, 151). A glance at Koken's world map showing the relation of land to sea during the Permic will show that Bussaco was in position to receive very heavy torrential deposits, being near the coast of that time.

SUMMARY TABLES

All of the data of the foregoing pages are summarized in the following series of tables. Table I is designed to show quickly in what horizons and country any species of eurypterid has been found. Table II, summarizing Table I, gives at a glance the numbers of species that are recorded from each horizon and from each country and also from each period. Table III gives in greater detail the localities in which remains have been found, but is particularly meant to give an accurate description of the mode of occurrence of every species, if the remains are fragmentary, to state how many fragments have been found, and if perfect to record with equal care the numbers found. Each table is complete in itself, but all three, on the other hand, should be used together since each one supplements the others.

TABLE III

Summary of the Distribution, Facies and Mode of Occurrence of the Eurypterida

SPECIES	HORIZON AND FACIES	LOCALITY	CONDITION
1. Beltina danai	Greyson shales, Belt Terrane	Montana	Hundreds of fragments; surface markings absent generally.
	Altyn limestone	Altyn, Montana; Johnson Creek, Alberta, Canada	Numerous fragments, some showing scale markings
2. Bembicosoma pomphicus	Wenlock shales and sandstones	Gutterford Burn, Pentland Hills, Edinburghshire, Scotland.	Two incomplete individuals
3. Dolichopterus breviceps	Normanskill shales and sandstones	Broom Street Quarry, Catskill, New York	A single carapace
4. D. frankfortensis	Schenectady shale	Schenectady (Dettbarn Quarry), Aqueduct, Rotterdam Junction Duanesberg, New York	About a dozen carapaces
5. D. laticeps	Zone K, Eurypterus waterlimes of Oesel	Rootziküll, Oesel	Two head shields
6. D. latifrons	Schenectady shale	Schenectady, New York	Two incomplete carapaces
7. D. macrochirus	Bertie waterlime	Williamsville, Litchfield, Waterville, New York	Three nearly complete individuals; a few fragments
8. D. otisius	Black shales in Shawangunk grit	Otisville, New York	About 30 carapaces some showing two attached tergites
		Delaware Water Gap, Pa.	A number of carapaces
9. D. siluriceps	Bertie waterlime	Williamsville, New York	A single carapace
10. D. stylonuroides	Black shales in Shawangunk grit	Otisville, New York	Three carapaces, and one specimen with carapace, swimming leg and three tergites
11. D. (?) testudineus	Bertie waterlime	Litchfield Herkimer Co., New York	A single carapace
12. Echinognathus clevelandi	Utica shale	Holland Patent, Oneida Co., New York	Fragment of a thoracic segment
13. Eurypterus abbreviatus	Downton Castle sandstone	Kington, Herefordshire, England	One incomplete telson
14. E. acuminatus	Spirifer elevata shales, Upper Ludlow group Olive shales of Temeside group	Ludlow railroad cut, Ludlow, Shropshire, England	Several incomplete telsons and rare fragments
15. E. approximatus	Waverly	3 mi. s. of Warren, Warren Co., Pennsylvania	A single specimen with carapace and nine somites

16. E brewsteri	Arbroath flags, Caledonian Old Red Sandstone	Kelly Den, near Arbroath, Forfarshire, Scotland	A carapace, portion of first thoracic segment; ovisac
17. E. brodiei	Lower part of Downton Castle sandstone	Purton, near Stoke Edith, Herefordshire, England	One almost entire individual and some fragments
18. E. cephalaspis	Downton sandstone	Kendal, Westmoreland, England	
19. E. chadwicki	Normanskill shales and sandstones	Broom Street Quarry, Catskill, New York	A single carapace
20. E. conicus	Wenlock shales and sandstones	Gutterford Burn, Pentland Hills, Edinburghshire, Scotland	A number of more or less complete individuals; limbs fragmentary.
21. E. cyclophthalmus	Wenlock shales and Sandstones	Gutterford Burn, Pentland Hills, Edinburghshire, Scotland	One specimen showing part of carapace and parts of all body segments
22. E. dekayi	Bertie waterlime	Near Buffalo, New York	Two nearly complete specimens
23. E. ? dewalquei	Famennian sandstone	Condroz, Belgium	Portion of cephalothorax and a few fragments
24. E. ? dewalquei var. longimanus	Famennian sandstone	Condroz, Belgium	Last segment of an appendage
25. E. dolichoschelus	Ludlow fish band	Dippal Burn, Greenock Burn, etc., Lesmahagow, Lanarkshire, Scotland	Numerous fragments
	Glauconome shale in div. 9, P & H.	Hagshaw Hills, Lanarkshire, Scotland	
	Lanarkian, div. 9, Peach& Horne	Dippal Burn, Lesmahagow, Scotland	
26. E. douvillei	Rothliegende sandstone	Büssaco, Portugal	One almost complete individual, well preserved, appendages absent
27. E. fischeri	Zone K Eurypterus waterlimes of Oesel	Rootziküll, Wita, Attel, etc. Oesel	Large numbers preserved entire with unaltered chitin.
	Zone K Eurypterus waterlimes of Oesel	Lodjal, S. E. Oesel	Traces
	Upper Siluric limestone of Podolia	Kamieniec podolski, Dumanow, Zawale, Studzienica, Zaluczs, all in Podolia	Fragments only
28. E. fischeri var. rectangularis	Zone K Eurypterus waterlimes of Oesel	Rootziküll, Oesel	Occasional incomplete specimens; carapace with two tergites and 2 appendages
29. E. hibernicus	Kiltorcan sandstones and flagstone, Upper Old Red	Kiltorcan, Kilkenny Co., Ireland	Nearly a dozen fragments, including 2 carapaces, 2 or 3 somites, fragments of appendages
30. E. imhofi	Roof shale in Carbonic of Bohemia	Wilkischen, near Pilsen, Bohemia	Several nearly entire individuals; well preserved

TABLE III—Continued

SPECIES	HORIZON AND FACIES	LOCALITY	CONDITION
31. E. lacustris	Bertie waterlime	Williamsville and Buffalo, New York; Bertie, Ontario	Well preserved specimens abundant
		Black Rock, Erie Co., Union Springs, Cayuga Co., New York	A few smaller specimens
32. E. lacustris var. pachychirus	Bertie waterlime	Buffalo, Erie Co., New York	An abdomen, two swimming legs several endognathites
33. E. lanceolatus	Pterygotus bed, div. 4 of Ludlow (Peach & Horne)	Lesmahagow, Lanarkshire, Scotland	Several nearly entire individuals and fragments
34. E. liniaris	Spirifer elevata shales, Upper Ludlow group	Ludford, S. of Ludlow, and Kington, Herefordshire	Telsons only
35. E. lohesti	Famennian sandstone	Condroz, Belgium	One carapace
36. E. maria	Black shales in Shawangunk grit	Otisville, Orange Co., New York	Abundant, well preserved, though incomplete; mostly immature; carapaces numerous
		Delaware Water Gap, Pa	Several carapaces
	Olive shales in Tuscarosa sandstone	Swatora Gap, Pa.	Several small carapaces
37. E. microphthalmus	Manlius limestone	Cazenovia, Madison Co.; Onondaga Valley, Litchfield, Jerusalem Hill, Herkimer Co.	One nearly complete and many cephala
	Monroe (Put-in-Bay) limestone	Put-in-Bay Island, Lake Erie	Two cephala
38. E. minor	Wenlock shales and sandstones	Gutterford Burn, Pentland Hills, Edinburghshire, Scotland	One nearly entire individual, a carapace and fragments
39. E. moyseyi	Clay nodules in Coal measures	Northwest Ilkeston, Derbyshire, England	Two specimens, posterior abdominal segments missing
40. E. pittsfordensis	Pittsford shale	Pittsford, Monroe Co., New York	Rare and fragmentary; a few nearly complete individuals
41. E. pristinus	Schenectady shale	Dettbarn Quarry, Schenectady, New York	One carpace and doubtful patches
42. E. ? (Dolichopterus?) prominens	Clinton sandstones	Cayuga Co., New York	A single carapace
43. E. pustulosus	Bertie waterlime	Buffalo, New York	Two carapaces and one postabdomen, all fragmentary

44. E. pygmaeus	Downton Castle sandstone	Kington, Herefordshire, England	Carapace and portion of body; scattered fragments
	Olive shales, Temeside group	Ludford Lane and Ludlow railroad cut, Herefordshire, England	Fragmentary individuals common
45. E. ranilarva	Kokomo waterlime	Kokomo, Indiana	A few nearly complete; rare and poorly preserved
46. E. remipes	Bertie waterlime	Waterville, town of Westmoreland, Oneida Co.; Jerusalem (Wheelock's Hill, Litchfield, Herkimer Co.; Cedarville and Paria Hill, Herkimer Co.; near Oriskany, Cayuga junction, Cayuga Co., N. Y.	Numerous well preserved and many fragments
	Rondout waterlime	Seneca Falls, Seneca Co., New York	Typical specimens well preserved
47. E. ruedemanni	Schenectady shales	Near Rotterdam Junction, Schenectady Co., New York	A single carapace
48. E. scouleri	Burdie House limestone	Kirkton, near Bathgate Linlithgowshire, Scotland	Two carapaces and a few fragmentary abdomina
	Upper Old Red Sandstone	Kiltorcan, Kilkenny Co., Ireland	Three patches of integument; very doubtful
49. E. cf scouleri	Coal Measures of Silesia	Near Neurode, County of Glatz, Silesia	One incomplete carapace and two fragments of appendages
50. E. ? (Dolichopterus?) stellatus	Schenectady shales	Dettbarn Quarry, Schenectady, New York	Incomplete carapace and patches of integument
51. E. ? stevensoni	Cement stone group lowest Calciferous	Kimmerghame Quarry, Blackadder Water, near Dunce, Berwickshire, Scotland	Three fragments of body segments showing sculpturing
52. E. wilsoni	Downton sandstones	Ludlow's Pit, Radstock, Somersetshire, England	First six body segments only
53. E. sp. Barbour	Coal measures	One mile south of Peru, Nebraska	One almost complete individual
54. E. sp. Elles and Slater	Chonetes striatella beds Ludlow Bone-Bed Downton Castle sandstones Temeside shales	Ludlow district, Shrophire and Herefordshire	Various unidentifiable fragments probably representing several species of Eurypterus; rare in two lower horizons, common in the two higher
55. E. sp. Peach and Horne	Wenlock shales and sandstones	Near Straiton, Girvan, Scotland	Fragments

TABLE III—Continued

SPECIES	HORIZON AND FACIES	LOCALITY	CONDITION
56. E. sp. Laurie	Wenlock shales and sandstones	Gutterford Burn, Pentland Hills, Edinburghshire, Scotland	Numerous unidentifiable fragments
57. E. sp. (?) Laurie			
58. E. sp. Moberg	Oved-Ramsåsa formation Zone 1	Bjersjölagård, Sweden	Abundant fragments
59. E. (Adelopthalmus) granosus	Middle Saarbrücker Schiefer	RR. shaft at Jägersfreude, ¾ mi. from Saarbrücken, Germany	One incomplete individual
60. E. (Anthraconectes) mansfieldi	Carbonic shale below Darlington cannel coal	Near Cannelton, Darlington Township, Beaver Co., Pennsylvania	Several nearly complete and a number of fragments
61. E. (Anthraconectes) mazonensis	Coal Measures (Alleghany)	Mazon Creek, Grundy Co., Illinois	Single ventral impression of incomplete individual
62. E. (Anthraconectes) nebraskensis	Coal measures	One mile south of Peru, Nebraska	Abundant and well preserved; some only carbonaceous films
63. E. (Anthraconectes) pennsylvanicus	Arenaceous shale in Coal Measures	Rooker Farm, Pithole City, Venango Co., Pennsylvania	A single small carapace
64. E. (Onychopterus) kokomoensis	Kokomo waterlime	Kokomo, Indiana	One nearly perfect and well preserved; three fairly good specimens
65. E. (Tylopterus) boylei	Guelph dolomite	Ontario, Canada	A single incomplete though well preserved individual
66. Eusarcus acrocephalus	Ee_1 Kuchelbader graptolite sh.	Dvorec, near Prague, Bohemia	Carapace and first eight body segments; better preserved than other specimens in same bed
67. E. (?) cicerops	Black shales in Shawangunk grit	Otisville, New York	Rare; several carapaces and a preabdomen
68. E. linguatus	Normanskill shales and sandstones	Broom Street Quarry, Catskill, New York	Two fragmentary carapaces
69. E. logani	Eramosa beds, Niagaran	Eramosa river, near Guelph, Ontario, Canada	Numerous fragments very poorly preserved; post-abdominal segments, spines, telsons, a metastoma

70. E. (?) longiceps	Schenectady shale	Schenectady, New York	A number of carapaces; one with fragmentary preabdomen attached
71. E. newlini	Kokomo waterlime	Kokomo, Indiana	Four nearly complete, poorly preserved, showing later growth stage
72. ? E. obesus	Trochus or Platyschisma beds (5 of Peach and Horne)	Lesmahagow, Lanarkshire	One almost entire, and fragments
73. E. punctatus	Upper Ludlow	Whitcliff, near Ludlow, Herefordshire, Kendal, Westmoreland, England	Detached appendages and fragmentary remains
	Lower Ludlow	Church Hill, Leintwardine, Shropshire, England	
	Wenlock limestone and shale	Dudley, Worcestershire, England	Five abdominal segments and fragments
74. E. aff. punctatus et acrocephalus	Ee_1 β Kuchelbader graptolite shales	Podol Dvorce, Bohemia	A single endognath
75. E. raniceps	Div. 3 (Peach and Horne) Ceratiocaris beds	Logan water, near Lesmahagow, Lanarkshire, Scotland	One incomplete and fragmentary individual
76. E. scorpioides	Div. 3 (Peach and Horne) Ceratiocaris beds	Logan water, near Lesmahagow, Lanarkshire, Scotland	One nearly complete individual
77. E. scorpionis	Bertie waterlime	Williamsville and Buffalo, New York	Twenty specimens, 7 nearly entire, one of a young individual
78. E. scoticus	Wenlock shales and sandstones	Gutterford Burn, Pentland Hills, Edinburghshire, Scotland	Numerous fragments
79. E. simonsoni	Zone K, Eurypterus waterlimes of Oesel	Quarry at Wita, near Rootziküll, Oesel	One incomplete individual and one fragment of a foot
80. E. triangulatus	Schenectady shale	Dettbarn Quarry, Schenectady, New York	Three incomplete specimens, 3 carapaces, one preabdomen
81. E. vaningeni	Dark shales 21 feet below base of Vernon shales	Near Farmer's Mills, Oriskany Creek, 3 mi. S. of Clinton, New York	Two carapaces; a few fragments, and one carapace with nearly complete preabdomen
82. Glyptoscorpius caledonicus	Calciferous sandstone	Lennel Braes, Coldstream and Cockburnspath, Berwickshire, Scotland	Combs only
83. G. peronatus	Calciferous sandstone	River Esk, 4 mi. S. of Langholm, Dumfriesshire, Scotland	Carapaces with 5 body segments attached; specimen incomplete
84. Hastimima whitei	Santa Catharina system	N. E. of Minas, Santa Catharina, Brazil	Three fragments of integument showing surface markings
85. H. sp. Seward	Witteberg shales	Cape Colony, South Africa	One fragment of body segment showing surface markings

TABLE III—Continued

SPECIES	HORIZON AND FACIES	LOCALITY	CONDITION
86. Hughmilleria magna	Schenectady shale	Dettbarn Quarry, Schenectady Co., New York	Carapaces abundant; portions of abdomen fragmentary; preservation poor
		Duanesburg and Rotterdam Junction, Schoharie Co., New York	A few carapaces
87. H. shawangunk	Black shales in Shawangunk grit	Otisville, New York	Very abundant; most nepionic forms
		Delaware Water Gap, Pennsylvania	Several macerated carapaces; one segment showing sculpture
	Olive shales in Tuscarora sandstone	Swatora Gap, Pennsylvania	Several small carapaces
88. H. socialis	Pittsford shale	Pittsford, Monroe Co., New York	Very abundant; entire individuals rather rare
89. H. socialis var. robusta	Pittsford shale	Pittsford, Monroe Co., New York	One nearly entire abdomen; two somites; an imperfect metastoma
90. H. cf. socialis	Keefer sandstone, base of Salina	Pennsylvania—Maryland border	Numerous fragments badly crushed, difficult of identification
91. Megalograptus welchi	Liberty limestone, middle Richmond	Near Clarkesville, Clinton Co., Ohio	Two fragmentary endognaths, one post-abdominal somite
92. Strabops thacheri	Potosi limestone	Flat River, St. François Co., Missouri	One nearly perfect specimen
93. Pterygotus anglicus	Tealing beds, Pterygotus beds of Carmylie, Acanthodian beds of Turin Hill, the Arbroath flags etc. all of the Caledonian Old Red Sandstone series	Babruddy, Perthshire; Leysmill near Arbroath, Turin Hills, near Reswallie, Tealing and Carmylie, and elsewhere in Forfarshire, Scotland	Many nearly complete individuals and numerous *disjecta membra*
94. P. arcuatus	Lower Ludlow	Leintwardine, Shropshire, England	A body segment, two endognaths and some fragments
95. P. atlanticus	Dalhousie limestone (Campbellton beds)	Campbellton, New Brunswick	Three specimens: a free chela, coxa of a swimming leg, and a small portion of a metastoma
96. P. australis	Upper Siluric flags (Victorian series)	Melbourne, Australia	Four fragments
97. P. barrandei	Ee$_1$ β Kuchelbader graptolite shales	Podol Dvorce, near Prague, Bohemia	A few fragments
	Ee$_2$ β Budňaner limestone	Podol Dvorce, Dlouhá hora, Bohemia	
98. P. beraunensis	Ee$_1$ β Kuchelbader graptolite sh.	Podol Dvorce, near Prague, Bohemia	A few endognaths only

99. P. bilobus var. acidens	Divisions 3 and 4 (Peach and Horne) i.e. the Ceratiocaris and Pterygotus beds of the Ludlow	Lesmahagow, Lanarkshire, Scotland	One antenna, one cephalon, and nearly all the segments of one individual
100. P. bilobus var. crassus			At least one perfect specimen
101. P. bilobus var. inornatus			Many perfect fragments all altered by pressure
102. P. bilobus var. peronatus			An almost entire individual and several incomplete carapaces
103. P. blahai	Ee$_2$ Budňaner limestone	Visňovka near Lochkov, Bohemia	Broken fragments of swimming foot
104. P. bohemicus	Ee$_1$ β Kuchelbader graptolite shales	Dvorec	Fragments only
	Ee$_2$ Budňaner limestone	Near Budnian, below Karlstein; Dlouhá hora near Karlstein, Bohemia	Fragments only
105. P. aff. bohemicus	Ff$_1$ Lochkover limestone	Černá rokle near Kosor, Bohemia	A single claw and part of an abdomen
106. P. buffaloensis	Bertie waterlime	Buffalo, New York	A few nearly perfect individuals and several fragments
107. P. cobbi	Bertie waterlime	Near Buffalo, New York	Two rami of the chelate appendage
108. P. cobbi var. juvenis	Bertie waterlime	Schorley's Farm, Litchfield, Herkimer Co., New York	Two nearly entire specimens
109. P. fissus	Ee$_2$ Budňaner limestone	Dlouhá hora, near Karlstein, Bohemia	A single claw
110. P. gigas	Downton Castle sandstones	Kington Herefordshire	Fragments numerous
	Downton Castle sandstones (massive sandstone bed)	Ludlow district, Herefordshire and and Shropshire, England	Fragments rare
	Olive shales and Temeside Bone-Bed in Temeside group	Ludlow district, Herefordshire and Shropshire, England	Fragments common
111. P. kopaninensis	Ee$_2$ Budňaner limestone	Near Kopanina, Bohemia	Rare and incomplete fragments
112. P. ludensis	Downton Castle sandstones	Ludlow district Herefordshire and Shropshire, England	Fragments rare
	Olive shales and Temeside Bone-Bed, Temeside group	Ludlow district Herefordshire and Shropshire, England	Fragments common
	Transition beds to Old Red	Trimpley, near Kidderminster, Herefordshire, England	One specimen with nearly all of body somites and telson; a few other fragments
113. P. macrophthalmus	Bertie waterlime	Williamsville, Erie Co.; Litchfield, Herkimer Co.; Waterville, Oneida Co., New York	Three nearly perfect specimens and a few fragments

TABLE III—Continued

SPECIES	HORIZON AND FACIES	LOCALITY	CONDITION
114. P. minor	Indurated shale overlying Arbroath flags	Farnell, Forfarshire, Scotland	One small almost perfect specimen
115. P. monroensis	Pittsford shale	Pittsford, Monroe Co., New York	One cephalothoracic shield
116. P. (Eusarcus ?) nasutus	Normanskill shale	Broom Street Quarry, Catskill, New York	Several carapaces
	Schenectady shale	Schenectady, Aqueduct, and Duanesburg, Schenectady Co., New York	Several carapaces
117. P. nobilis	Ee_1 β Kuchelbader graptolite shales	Podol Dvorce, Bohemia	Fragments only
	Ee_2 Budňaner limestone	Near Kolednik Bohemia	
118. P. normanskillensis	Normanskill shale	Broom Street Quarry, Catskill, New York	Carapaces; possibly some telsons
119. P. problematicus	May Hill sandstone	Abelish, Eastnor Park, near Ledbury, Herefordshire	Chela only
	Throughout entire Upper Ludlow group	At Whitcliff and many localities in and near Ludlow, Herefordshire	Fragments rare
	Platyschisma beds, Temeside group	Ludlow district	Fragments abundant, but poorly preserved. No entire individuals
	Downton Castle sandstones, Temeside group	Bradnor Hill, Kington, and near Ludlow, Herefordshire	
	Olive shales, Upper Temeside group	Ludlow district	
	Temeside Bone-Bed	Ludlow district	
120. P. cf. problematicus Salter (Semper)	Ee_2 Budňaner limestone	Kolednik Bohemia	A single fragment of a chela
121. P. prolificus	Schenectady shales	Schenectady, Aqueduct, Rotterdam Junction, Duanesburg, Schoharie Junction, Uly Crreek, New York	A number of fairly complete carapaces
122. P. ? stylops	Downton Castle sandstones	Kington, Herefordshire, England	Anterior portion of a single carapace
123. P. taurinus	Ledbury shales	Ewyas Harold, Herefordshire	A nearly complete carapace, portions of telson and body segment, and fragments
124. P. sp. Siemiradzki	Devonic limestone	Skala, Podolia	A single telson

125. P. sp. H. Woodw.	Knoydart formation	McArras Brook, Antigonish Co., Nova Scotia	Specifically indeterminable fragments
126. P. (Erettopterus) banksii	Ludlow Bone-Bed	Ludlow	Many specimens, none complete; fragments abundant
	Platyschisma-beds in Temeside group	Ludlow	
	Downton Castle sandstones	Ludlow Lane, Whitcliffe, Parlan, exterior slope of Woolhope Valley, Kington, Herefordshire	
	Olive shales, Upper Temeside group	Ludlow England	
127. P. (Erettopterus) globiceps	Shales in the Shawangunk grit	Otisville, New York	No entire specimens; several carapaces, a few body segments, a swimming leg several telsons; four immature individuals
	Shales in Tuscarora sandstone	Swatora Gap, Pa	Several small carapaces
128. P. (Erettopterus) cf. globiceps	Shales in the Shawangunk grit	Delaware Water Gap, Pennsylvania	A small distorted carapace
129. P. (Erettopterus) grandis	Bertie watertime	Buffalo, New York	A single telson
130. P. (Erettopterus) osiliensis	Zone K, Eurypterus waterlimes of Oesel	Rootziküll, Oesel	Many separated members; no entire individuals
	Pterygotus marl	Visby, Gotland	Fragmentary, but abundant
	Transition beds to Devonic of Galicia	Zalesczyki, Galicia	Fragments, determined with difficulty
131. Slimonia acuminata	Div. 3, 4, 5 & 6 (Peach and Horne), Ludlow	Banks of Logan Water, Lesmahagow, Lanarkshire	One nearly perfect specimen; dismembered organs abundant
132. S. cf. acuminata (Seemann)	Ee$_2$ Budňaner limestone	Dlouhá hora, Bohemia	One fragment of an ectognath
133. S. dubia	Wenlock shale and sandstone	Gutterford Burn, Pentland Hills, Edinburghshire, Scotland	Badly preserved carapace and parts of first eleven somites
134. Stylonurus beecheri	Chemung sandstones	Warren, Warren Co., Pennsylvania	One incomplete individual
135. S. ensiformis	Turin beds, Caledonian Old Red Sandstone	Turin Hill Quarries, near Reswallie, Forfarshire	A single incomplete telson
136. S. ? limbatus	Schenectady shale	Schenectady and Duanesburg, Schenectady Co., New York	Six carapaces, two doubtfully identified
137. S. logani	Pterygotus beds, div. 4 (Peach and Horne)	Logan Water, Lesmahagow, Lanarkshire	One incomplete specimen, showing carapace, ten body segments and a few appendages
138. S. macrophthalmus	Wenlock shales and sandstones	Gutterford Burn, Pentland Hills, Edinburghshire, Scotland	One complete individual; several fragments

TABLE III—Continued

SPECIES	HORIZON AND FACIES	LOCALITY	CONDITION
139. S. megaolps	Olive shales, Temeside group	Ludlow railroad cut, Herefordshire	Fragments common, carapaces especially, but all broken
140. S. modestus	Normanskill shale	Broom Street Quarry, Catskill, New York	Several small carapaces, portions of the abdomen, a leg
141. S. myops	Shales in the Shawangunk grit	Otisville, New York	One entire individual poorly preserved; numerous carapaces; some with attached somites
		Delaware Water Gap, Pennsylvania	Several large and small carapaces
142. S. ornatus	Wenlock shales and sandstones	Gutterford Burn, Pentland Hills, Scotland	Three or four fragments including portions of carapace, abdomen, appendages and telson
143. S. powriei	Turin beds, Caldeonian Old Red Sandstone	Turin Hills, near Pitscandly, Forfarshire, Scotland	One nearly complete individual
144. S. symondsii	Cornstones middle Old Red	Rowlestone, south of Hay, Brecknockshire, England	One well preserved carapace
145. S. (?) scabrosus	Calciferous shales	Glencartholm, Eskdale, Scotland	One incomplete specimen, showing cephalon, portions of first 10 somites and fragments of appendages
	Lower Carbonic shales and clay iron stones	Sedgley, near Dudley, Staffordshire, England	One incomplete individual with some of the appendages attached
146. S. ? wrightianus	Portage sandstones	Italy, Yates Co., New York	A single, two-jointed fragment; may be part of appendage
147. S. (Ctenopterus) cestrotus	Shales in Shawangunk grit	Otisville, New York	Rare form; a few nearly complete individuals; a few carapaces
148. S. (Ctenopterus) elegans	Wenlock shales and sandstones	Gutterford Burn, Pentland Hills, Scotland	Five fragmentary specimens certainly, two more probably
149. S. (Ctenopterus) excelsior	Catskill sandstone	Andes, Delaware Co., New York	External mold of complete carapace
		Wyoming Co., New York	Fragmentary carapace
150. S (Ctenopterus) multispinosus	Pittsford black shale	Pittsford, Monroe Co., New York	Six incomplete endognathites and one somite

151. S. (Drepanopterus) bembicoides...	Wenlock shales and sandstones	Gutterford Burn, Pentland Hills, Scotland	Two incomplete specimens
152. S. (Drepanopterus) lobatus.......	Wenlock shales and sandstones	Gutterford Burn, Pentland Hills, Scotland	One nearly complete individual, two or three fragments
153. S. (Drepanopterus) longicaudatus..	Kokomo waterlime	Kokomo, Indiana	Form not described
154. S. (Drepanopterus) pentlandicus..	Wenlock shales and sandstones	Gutterford Burn, Pentland Hills	Several nearly perfect and two fragmentary individuals
155. S. (Tarsopterus) scoticus.........	Caldeonian Old Red Sandstone	Montroman Muir, near the Forfar and Montrose Pike, Forfarshire	One carapace and an almost entire individual
156. S. sp α Clarke and Ruedemann...	Shales in Shawangunk grit	Otisville, New York	Two fragments of leg joints of uncertain specific relations
157. S. sp. β Clarke and Ruedemann ...	Shales in Shawangunk grit	Otisville, New York	Terminal joints of leg
158. S. sp. γ Clarke and Ruedemann ..	Shales in Shawangunk grit	Otisville, New York	Fragments of segment and of integument
159. S. sp. δ Clarke and Ruedemann. ..	Shales in Shawangunk grit	Otisville, New York	

SYNONYMY

In order to facilitate the use of the preceding tables, I shall give here a synonymy which is not complete, but is intended only for the convenience of anyone looking for a species which has been revised, and which would not appear under the genus to which it was originally ascribed. Such a synonymy is particularly necessary for species described in foreign literature. Most of the revisions have been made by Clarke and Ruedemann for American and some European species, by H. Woodward for species in Great Britain, by Semper for those in Bohemia originally described by Barrande, and by numerous other writers who have revised only single species.

Original Name	*Present Name or Status*
Adelopthalmus granosus Jordan	Eurypterus (Adelopthalmus) granosus (Jordan)
Carcinosoma newlini Claypole	Eusarcus newlini (Claypole)
C. ingens Claypole	Eusarcus newlini (Claypole)
Ceratiocaris grandis Pohlman	Pterygotus (Erettopterus) grandis (Pohlman)
Dolichocephala lacoana Claypole	Stylonurus (Ctenopterus) excelsior Hall
D. macrocheirus Hall	Dolichopterus macrochirus Hall
D. mansfieldi C. E. Hall	Eurypterus (Anthraconectes) mansfieldi (C. E. Hall)
Drepanopterus bembycoides Laurie	Drepanopterus bembicoides Laurie
D. bembicoides Laurie	Stylonurus (Drepanopterus) bembicoides (Laurie)
D. lobatus Laurie	Stylonurus (Drepanopterus) lobatus (Laurie)
D. longicaudatus Clarke and Reudemann	Stylonurus (Drepanopterus) longicaudatus (Laurie)
D. pentlandicus Laurie	Stylonurus (Drepanopterus) pentlandicus (Laurie)
Echinocaris wrightiana Jones and Woodward	Stylonurus (?) wrightianus (Dawson)
E. wrightiana Etheridge, Woodward and Jones	Stylonurus (?) wrightianus (Dawson)
Eurypterus acrocephalus Semper	Eusarcus acrocephalus (Semper)
E. beecheri Hall	Stylonurus beecheri (Hall)
E. beecheri Hall and Clarke	Stylonurus beecheri (Hall)
E. chartarius Salter	Eurypterus lanceolatus Salter
E. ? icerops Clarke	Eusarcus (?) cicerops Clarke
E. eriensis Whitfield	Eurypterus microphthalmus Hall
E. giganteus Pohlman	Eurypterus pustulosus Hall
E. lacustris Hibbert	Eurypterus lacustris Harlan
E. lacustris Hall var pachychirus Hall	Eurypterus pachychirus Hall
E. laticeps Schmidt	Dolichopterus laticeps (Schmidt)

Original Name	*Present Name or Status*
E. mansfieldi James Hall	Eurypterus (Anthraconectes) mansfieldi (C. E. Hall)
E. (Arthropleura) mammatus Salter	Not a eurypterid
E. maria (in part) Clarke	Pterygotus (Erettopterus) globiceps Clarke and Ruedemann
E. megalops Clarke and Ruedemann	E. ruedemanni O'Connell
E. megalops Salter	Stylonurus megalops (Salter)
E. pennsylvanicus James Hall	Eurypterus (Anthraconectes) pennsylvanicus C. E. Hall
E. obesus H. Woodward	Eusarcus obesus (H. Woodward)
E. myops Clarke	Stylonurus myops Clarke
Cf. E. potens James Hall	Eurypterus
E. pugio Barrande	Doubtful determination, no standing
E. punctatus H. Woodward	Eusarcus punctatus (Salt.)
E. punctatus Salter	Eusarcus punctatus (Salt.)
E. aff. punctatus Woodw. et acrocephalus Semper	Eusarcus punctatus (Salt.)
E. remipes Logan	Eurypterus lacustris Harlan
E. remipes Bronn and Roemer	Eurypterus lacustris Harlan
E. scoticus Laurie	Eusarcus scoticus (Laurie)
E. scouleri (?) Salter	Eurypterus hibernicus (Baily)
E. simonsoni Schmidt	Eusarcus simonsoni (Schmidt)
E. scorpioides H. Woodw	Eusarcus scorpioides (H. Woodw.)
E. stylus James Hall	Eurypterus (Anthraconectes) mansfieldi (C. E. Hall)
E. symondsii Salter	Stylonurus symondsii (Salter)
E. tetragonophthalmus Fischer	Eurypterus fischeri Eichwald
Eurysoma newlini Claypole	Eusarcus newlini (Claypole)
Eusarcus grandis Grote and Pitt	Eusarcus scorpionis Grote and Pitt
E. scorpionis Pohlman 1881	Eusarcus scorpionis G & P *not* E. scorpionis Pohlman 1886
E. scorpionis Semper	Eusarcus scorpionis G & P
E. scorpionis Seeman	Eusarcus scorpionis G & P
Equisetides wrightiana Dawson	Stylonurus (?) wrightianus (Dawson)
E. wrightiana Wright	Stylonurus (?) wrightianus (Dawson)
Himantoperusa cuminatus Salter	Slimonia acuminata (Salter)
H. acuminatus D. Page	Slimonia acuminata (Salter)
H. bilobus Salter	Pterygotus bilobus var. inornatus (Salter)
H. banksii Salter	Pterygotus (Erettopterus) banksii (Salter)
H. lanceolatus Salter	Eurypterus lanceolatus (Salter)
H. maximus Salter	Slimonia acuminata (Salter)
H. perornatus Salter	Pterygotus bilobus var. perornatus Woodw.
Pterygotus acuminatus Salter	Slimonia acuminata (Salter)

Original Name	*Present Name or Status*
P. acuticaudatus Pohlman	Pterygotus buffaloensis (Pohlman)
P. banksii Salter	P. (Erettopterus) banksii Salter
P. buffaloensis Pohlman	P. buffaloensis (Pohlman)
P. cobbi (P. cummingsi) Semper	P. cobbi Hall
P. comes Barrande	P. bohemicus Barrande
? P. cummingsi Grote and Pitt	P. buffaloensis (Pohlman)
P. cummingsi Grote and Pitt	P. cobbi Hall
P. cyrtochela Barrande	Doubtfully identified, no standing
P. expectatus Barrande	Doubtfully identified, no standing
P. globicaudatus Pohlman	Eurypterus pustulosus Hall
P. globicaudatus Laurie	Eurypterus pustulosus Hall
P. hibernicus Baily	Eurypterus hibernicus (Baily)
P. macrophthalmus ? Pohlman	P. buffaloensis (Pohlman)
P. mediocris Barrande	Doubtfully identified, no standing
P. osborni Hall	Pterygotus macrophthalmus Hall
P. perornatus Salter	P. bilobus var. perornatus Woodw.
P. perornatus var. plicatissimus	P. bilobus var. perornatus Woodw.
P. problematicus Agassiz	P. problematicus Salter
P. problematicus Banks	P. gigas Salter
P. problematicus Strickland and Salter	P. problematicus Salter
P. punctatus Salter	Eusarcus punctatus (Salter)
P. pugio Barrande	Doubtfully identified, no standing
P. quadricaudatus Pohlman	Pterygotus buffaloensis (Pohlman)
P. raniceps (Woodw.)	Eusarcus raniceps (Woodw.)
P. sp. Whiteaves	P. atlanticus Clarke and Ruedemann
? P. sp. Sarle	P. monroensis Sarle

CHAPTER II

A RÉSUMÉ OF THE OPINIONS ON THE HABITAT OF THE EURYPTERIDA

From 1818 when the first Eurypterus was discovered in America by Dr. S. L. Mitchell until 1900, the order of the Eurypterida was held to be made up of marine organisms. This belief in the marine habitat of the oldest Arthropoda known suddenly became the centre of contention at the beginning of the present century in spite of its long period of security. As soon as geologists considered the possibility of origins other than marine for conglomerates, shales and even limestones, there arose discussion as to the nature of the beds in which eurypterids had been found and opinions were perceived to be divergent. It is of interest, then, to take up a systematic review of the literature for the last hundred years and to note what has been the general opinion of geologists and palaeontologists about the bionomy of the eurypterids, and to note also the change from an unquestioning assumption that the habitat was marine, to doubt and finally to opposition to the old idea.

Mitchell considered the form which he found in Westmoreland, New York, to be the impression of a catfish and so placed it under the genus Silurus, noting that the nearest living relative was the electrical silure of the Nile (**180**). He had no idea of the great age of the fossil, but supposed it to have been the remains of a fish which had lived in the Mohawk which was then generally believed to have been dammed so that the river waters and their fauna spread over a wide area. It is curious to see that the first man to find a eurypterid should, without any clear idea of its age or its true nature, have supposed that it lived in a river. This was mere speculation on his part and of no real significance. In 1825, however, Dekay, recognizing its true relation to the arthropods, established a new genus, Eurypterus, for it. He considered it most nearly related to the genera Apus, Binoculus and Lepidurus among modern forms, and placed it with the crustaceans of the order Branchiopoda. He mentions no other fossil associates, nor does he make any statement concerning the habitat, but he evidently considered it marine, for had he not, it is only natural to suppose that he would have made some statement to that effect, since it would have been a new and, indeed, a startling idea to advance. In 1841 Conrad, writing of the Eurypterus from the Bertie says (**44**, 38): "It has been suggested that this genus was of fresh water origin, but the presence of fucoids in the same stratum where the Eurypterus occurs, and the absence of the slightest evidence of a fresh water deposit in any part of the Silurian system, leave no room to doubt that this singular crustacean inhabited the sea." Conrad did not state who the bold spirit was that made such an original suggestion and his reasons for rejecting this explanation are unconvincing, because so-called *fucoids* are not necessarily marine, and non-marine deposits are now extensively known from the Siluric. Furthermore, even if the "fucoids" prove to be graptolites, as now claimed by Ruedemann, a non-marine habitat for the Eurypterus is not precluded. All the early writers seem to have agreed to consign the eurypterids to the class of the Crustacea, and to maintain for them a marine habitat. It has taken many years of patient labor for the students of the anatomy of these organisms and of the taxonomic relations of the Eurypterida to the Crustacea, to Limulus and to the scorpions, to convince the geological world that the Eurypterida are not Crustacea, but belong to the class Arachnida. The work has only just begun of convincing that same geological world that the habitat never was marine, but always fluviatile.

For nearly fifty years after Conrad made his statement authors described new species, erected new genera and worked out the affinities of the eurypterids to Limulus, but they gave not a thought to the habitat. It was not until 1889 that a direct reference was again made to the habitat. In Nicholson and Lydekker's *Manual of Paleontology* (**196**) we find the statement that "the nature of the deposits in which the remains of the Eurypterids are found, and of the fossils associated with them, would prove that these animals were essentially marine, their habits, probably being very similar to those of the existing King-crabs. It is, however, possible that certain of the Eurypterids were inhabitants of brackish or even of purely fresh waters" (**196**, 544).

In 1893, Malcolm Laurie, studying the eurypterid remains in the "Upper Silurian" of Scotland, i.e. the Siluric as generally used in America, found in those rocks of the Pentland Hills only one other fossil, *Dictyocaris ramsayi*, a crustacean (?) (**144**). The large eyes in most of the eurypterids which he found caused him to think that they must in some way be due to the conditions under which the creatures lived, and from a comparison with recent forms he was led to believe that the eurypterids lived in deep water, whether marine or not he does not say, but the former seems to be implied.

Amadeus W. Grabau writing in 1898 of the eurypterids said: "these crustacea were undoubtedly marine" (**81**, 362) thus accepting the usual classification and also the current opinion as to the habitat. On the other hand, Frech (**70**) at about the same time, said that the most evident proof of the retreat of the sea in the formation of the Old Red sandstone in England was the appearance in the Devonic of the eurypterids from the Baltic. This marks the beginning of the change in ideas and embodies the first statement contrary to the prevailing opinion that the habitat of the eurypterids was marine.

The period during which it was either tacitly assumed or definitely stated that these extinct merostomes had lived in the sea was thus brought to a close. There had been a few hints of a possible non-marine existence, but on the whole geologists and palaeontologists had for eighty years been agreed upon the marine habitat.

With the beginning of the new century we find a radical and sudden change of opinion. Chamberlin in his paper on "The Habitat of the Early Vertebrates" gives a philosophical discussion of the question which is extremely interesting and suggestive, though not backed up by much data. He calls attention to the fact that eurypterids and fishes are found associated in the Ludlow (Upper Siluric) of England, in the Island of Oesel in the Russian Baltic, in Podolia, Russia, in Galicia, and in the Waterlime group of North America. "The physical conditions in all these cases seem to have been peculiar," he continues, "and in the case of the Waterlime group they were singularly so, for they permitted a host of these large Eurypterids and other Crustaceans to flourish in seeming luxuriance, while only a meagre and pauperate marine fauna found an occasional entrance into the series. The conditions seem to have been congenial to the fish and Eurypterids, but not to a typical marine fauna" (**32**, 401, 402). The association of eurypterids and fishes in the Old Red sandstone where marine life was only occasional and meagre does not, as Chamberlin points out, imply prevalent marine conditions, for the Old Red and its homologues are the deposits of fresh water, and yet both the fishes and eurypterids found congenial conditions of life there. Chamberlin, recalling that fishes and eurypterids are found both earlier and later than the Devonic in marine deposits, puts the following question: "Were the fishes and eurypterids primarily marine and later became adapted to fresh water, or were they primarily fresh water forms which were occasionally carried out to sea and which later became adapted to salt water?" He reminds us that we are always in the habit of considering all life at first marine, then terrestrial, but, though this is true in general, the idea should not be held to with too great tenacity in every case. That the eurypterids may well furnish an example of an exceptional case is shown by various lines of evidence which Chamberlin cites. First, of the dozen genera of eurypterids known in 1900 only two or three of the least well known are without associations with formations regarded as fresh water; secondly, he says: "The relics found in marine sediments may be attributed to transportation from the land just as is one in the case of terrestrial plants and land insects not infrequently found in marine beds; but transportation in the opposite direction cannot be assigned" (**32**). One may, however, take exception to this last statement, for many marine forms migrate up rivers in the spawning season, as for instance, the crabs which go up the Hudson as far as Albany; and there are many marine molluscs which become adapted to conditions in rivers and may even in time migrate to the land. Chamberlin says further that the eurypterids are found in abundance in fresh-water deposits with only a few trails of annelids suggesting marine conditions; they are assumed, therefore, to have been marine first and then fresh water, but in this case also why may we not consider that these forms were carried out to sea, rather than that they lived in marine water?

In direct opposition to this line of argument, Zittel in his *Grundzüge der Palæontologie* (**327**, 527) offers the following: "The Eurypterida are found associated with Graptolites, Cephalopods, and Trilobites in the Ordovician of Bohemia* and North America; with marine Crustacea (Phyllocarids and Ostracods) in the Silurian; with Ostracoderms and Arthrodires in the Devonian; and with land plants, scorpions, insects, fishes, and fresh-water amphibians in the productive Coal Measures. It is apparent, therefore, that from being originally marine forms, they became gradually adapted to brackish, and possibly even to fresh water conditions."

Clifton J. Sarle in 1898 discovered a new eurypterid fauna at the base of the Salina, Middle Siluric, of western New York (**240**). This formation had hitherto been considered particularly barren of fossils, but Sarle found in two layers of the Pittsford black shales such an abundance of eurypterids that some layers were "literally packed" with their remains. The two shale beds are intercalated between dolomite layers which, Sarle remarks, represented more open water and were apparently unfavorable to the eurypterids. The occupation of the black shales by these animals "was apparently of comparatively short duration, merely an incursion, as it were, since the black shale all told does not exceed 2 feet in thickness. The fact that the eurypterids are often dismembered and their parts distributed over considerable areas, and that a dozen or more are frequently found side by side . . . . suggests that they may have been drifted up by a current. On the other hand, the fine preservation of much of the material, extending even to the delicate appendages, shows that the currents were very weak, thus practically leaving the animals in the position of death or molting" (**240**, 1086).

A. W. Grabau in his *Physical and Faunal Evolution of North America during Ordovicic, Siluric, and Early Devonic Time* (1909) makes the facts of distribution an argument in favor of a fluviatile habitat, thus calling attention to one of the most important aspects of the problem. "The Eurypterid fauna also occurs in the mud layers in the Shawangunk conglomerate, which hardly admits of any other interpretation than deposition by torrential rivers. This would make the urypterid fauna a fresh-water fauna, an interpretation which best corresponds with the distribution of these fossils geologically as well as geographically. The Salina series is best understood as a desert deposit. The absence of organic remains (with the exceptions noted), known to be abundant in all modern salt deposits of sea-margin origin; the thickness of the salt beds; their limitation to circumscribed basins, the red color of the lower shales, their mud-cracks, all point to a continental origin" (**84**, 245). Clarke in reference to this fauna says: "Our present knowledge of the habits of the merostome crustaceans derived both from the living and fossil forms, indicates the shallow water or barachois origin of all sediments in which these remains abound" (**36**, 302). He does not, however, accept Grabau's interpretation of a torrential origin for the Shawangunk deposits, but thinks rather that they were formed in an Appalachian Gulf cut off from the ocean on the east by the Shawangunk Mountains, the material being swept down from the land and forming a delta deposit, the terrestrial waters preventing a highly saline condition in the gulf. The eurypterids, according to this view, were marine forms caught in a gulf of not too great salinity.

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* No eurypterids have been found in the Ordovicic of Bohemia. This statement was not corrected in the 1910 edition of the *Grundzüge der Paläontologie*, p. 568, but has been corrected in the 1913 edition of the *Text-Book of Palæontology*, p. 779.

In the second volume of Chamberlin and Salisbury's *Geology* published in 1907, the eurypterid problem s again taken up as follows: "These giants among their kind seem clearly to have been aquatic forms, but whether they were primarily marine or fresh-water habitants is not so obvious. They are wholly extinct, and their habitat can only be inferred from their associations. Some crustacean fragments that seem to belong to the same sub-class as the eurypterids (Merostomata) have been found by Walcott in Pre-Cambrian beds, but their associates are too few to throw much light on this question, though they favor a marine habitat." (Walcott considers that they favor non-marine conditions.) "A very few eurypterids appear in the Ordovician, where they are associated with marine invertebrates. In the Waterlime beds they are associated with ceratiocarids and ostracods which are usually marine, and very rarely, with certain brachiopods which are marine. In the transition beds of England, Sweden, and Russia, the eurypterids are associated more freely with marine forms, but they are also associated with the seeds of land plants and with fish which in the succeeding stage, seem to have occupied land waters chiefly. In the Devonian and Carboniferous periods, in which the eurypterids reached their climax and passed into their decline, and where they seem to have been in their more natural relations, they are associated with land plants, scorpions, insects, fishes, and fresh-water amphibians, which seem to imply a fresh-water habitat. In the light of these facts, the more common inference has been that they were originally marine forms, and became adapted later to brackish and fresh-water conditions. The alternative inference is that they were originally denizens of the land waters, and that their remains were occasionally and sometimes quite freely carried out to sea by stream waters, and were thus fossilized with marine forms. Their occasional presence in the earlier periods is thus explained, while their seemingly sudden appearance in abundance and in gigantic forms in the closing Silurian, and their prominence in the land-water deposits of the Devonian and Carboniferous finds ready explanation in the fact that these are the first well-preserved fossil-bearing deposits of land waters. In these deposits the eurypterids often appear without any marine associates, while occasionally there are some marine or at least brackish water forms associated with them, implying either that they lived in brackish or salt water at times, or that their remains were carried out into such waters by the land streams or estuarine currents" (**33**, 412).

It is to be noted that European authors have said very little about the habitat of the eurypterids, though there are a few brief references. Geikie is the one exception, for he has a good deal to say about the merostomes and the faunas which occur with them. I shall at this point merely quote a few of these passages, written in the discussion of the Upper Siluric occurrences and of those in the Old Red sandstone. "Vegetable remains, some of which seem to be fucoids, but most of which are probably terrestrial and lycopodiaceous, abound in the Downton sandstone and passage-beds into the Old Red Sandstone. The eurypterid genera continue to occur, together with phyllocarids (*Ceratiocaris*) and vast numbers of the ostracod *Beyrichia* (*B. Kloedeni*). Prevalent shells are *Lingula cornea* and *Platyschisma helicites*. The Ludlow fishes are also met with" (**74**, 961). In the discussion of the deposition of the Old Red Sandstone in basins Geikie says: "An interesting confirmation of the view that these basins were isolated is supplied by the occurrence of what is believed to be the oldest lacustrine or fluviatile mollusk yet known, *Amnigenia* (*Anodonta*, *Archanodon*) *jukesii*. This shell has been found in the Upper Old Red Sandstone of Ireland and England associated with land-plants (*Archaeopteris*, *Sphenopteris*, *Bothrodendron*, *Ulodendron*, *Stigmaria*, *Calamites*), fishes (*Coccosteus*) and arthropods (*Eurypterus*)" (**74**, 1003, 1004).

Steinmann in his *Einführung in die Palæontologie* merely states that: "These remarkable Crustacea reaching a length of 2 meters appear in the Cambrian and Silurian in association with marine animals, in the Devonian they live with the armor-plated fishes in the Old Red, in the Carboniferous and Permic they are found in fresh-water" (**266**, 373).[1] Haug speaks of the salt and gypsum deposits of New York as lagoon formations, and includes here also the eurypterid beds at the end of the Siluric, thus reaching the same conclusion that many American authors have come to (**112**, 626).[2]

Walther in the chapter entitled *Das Aufblühen der Tierstämme in Silur* in the *Geschichte der Erde und des Lebens* has accepted the statement of several American geologists that the eurypterids were marine organisms saying that they lived in sea-water of normal salinity "as the section in North America proves with certainty" (**294**, 251). The reference cited for this proof is Sarle's paper on the fauna from the Salina of Western New York. The significance of this occurrence will be discussed below, but we may say at this point that this instance seems hardly to furnish proof positive of a marine habitat. He also calls attention to the restriction of the eurypterids to the black shales, and of the absence of marine forms in association with the merostomes.[3] He notes that in synchronous formations the eurypterids are found only in isolated localities. "Thus is the upper Silurian of Pennsylvania devoid of Eurypterus for a thickness of 500 meters" (**294**, 251). Walther's explanation of the isolated occurrences seems hardly to accord with the facts. He assumes that the regions devoid of eurypterid remains were great salty lakes cut off from the sea in which the eurypterids are supposed to have lived.[4]

Ernst Stromer in the *Lehrbuch der Palaeozoologie* has added nothing new to the opinions already expressed by so many authors. "It is an oft observed phenomenon that groups originally flourishing in the sea are confined during their decline in fresh-water. Here this applies only to the Gigantostraca [Merostomata], while the Xiphosura which appear formerly to have lived mainly in inland seas, are, today, however, marine only" (**269**, 308).

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[1] "Diese merkwürdigen, bis 2m. langen Krebse erscheinen in Kambrium und Silur in Begleitung von Meerestieren, im Devon leben sie mit Panzerfischen in Oldred, im Karbon und Perm finden sie sich in Süszwasserablagerungen."

[2] "Les formations lagunaires jouent un rôle peu important et l'on ne peut guère citer comment elles que des grès et des argiles rouges, qui, dans l'état de New-York et sur les bords de la Léna, renferment du gypse et du sel gemme, puis les *couches à Gigantostraces* et à Poissons, par lesquelles se termine souent le Silurien."

[3] "Hier folgt auf den fossilreichen Riffkalk ein dunkler Kalkmergel, der kein einziges der vorher hier so üppig gedeihenden Meerestiere enthält. Nur ein paar Schalen von Orthoceras wurden durch Stürme in die Bucht hineingetrieben, und einige genügsame Zweischaler lebten darin. Dann folgt ein schwarzer Mergel, reich an Eurypterus, und sobald dieses Gestein verschwindet, fehlen auch die Schildtiere und treten erst wieder auf sobald der schwarze Mergel nochmals erscheint." (**294**, 251.)

[4] Grosse Muschelkrebse (Leperditia) mögen hier einen salzigen Binnensee ohne Verbindung mit dem Meere belebt haben, so dasz die Schildtiere nicht hineinzudringen vermochten (**294** ,251).

During the year 1911 several papers on the Eurypterida appeared in America. Clarke still held to his former opinion that "the few eurypterids we know were doubtless marine, and the creatures gradually acquired the brackish-water habit at their climax, which seems to have eventually changed to a fresh-water life" (**37**, 280). Stuart Weller in his discussion of the nature of seas in which dolomites are formed, brings out several good points. "In such magnesian beds as are present in the Cayugan period of the Silurian [i.e., Middle and Upper Siluric] we find a most peculiar fauna, constituted almost wholly of the strange Eurypteroid Arthropods whose fossil remains are almost never found in association with typical marine faunas, but which are present in situations, such, for instance as the plant-bearing beds of the Pennsylvanian, which indicate that they must have lived in non-marine waters. The stratigraphic association of these Cayugan, Eurypterus-bearing beds with beds of salt and gypsum at once suggests that the waters of the period were highly saline and perhaps shallow; but, so far as I am aware, there is no inherent characteristic of the fossil Eurypterus which can in any way suggest that it may not have been a truly marine organism, and our conclusion that it was not such an organism is drawn from the physical surroundings of the fossil itself, rather than that the physical conditions are what we believe them to be on account of some peculiarity of the fossil" (**296**, 228). This point is well made, and is worth while remembering, namely, that there is nothing in the physical characters of the eurypterids to indicate that they lived in non-marine any more than in marine waters, but from their surroundings the former habitat is suggested. Moreover, the interpretation of the physical conditions of that time has not been based upon speculations about the characters of the eurypterids; it was definite knowledge about the physical conditions that makes it possible to say what must have been the character of the habitat of the eurypterids.

At the Kingston Meeting of Eastern Geologists in the spring of 1910 there was a warm discussion about the eurypterid habitat, Ruedemann, Schuchert, Hartnagel and others arguing in favor of the marine, Grabau in favor of the non-marine. The Waterlime formation was particularly under discussion, but though many arguments were brought up on both sides, neither was able to convince the other.

In the June number of the *Bulletin of the Geological Society of America* (1911) Clarke writing, on the "Relation of the Palaeozoic Arthropods to the Strand-Line," speaks of the size of the eyes of eurypterids and crustaceans as indications of the depth of water in which the forms lived. It was formerly supposed that crustaceans with large eyes had acquired them by adaptation to great depth of water. Clarke cites the case of a trilobite with enormous compound eyes living among many Cambric forms wholly devoid of lenses, and other examples of a contradictory character, so that the size of the eye cannot be taken as proof of either deep or shallow water, but rather implies that the complex, highly-specialized eyes of certain forms enables these individuals better to adapt themselves to either deep or shallow water conditions. Clarke reiterates the opinion that "the few early eurypterids we know were doubtless marine, and the creatures gradually acquired the brackish-water habit of their climax, which seems to have eventually changed to a fresh-water life" (**37**, 280).

In 1912 the most recent contribution to the study of North American eurypterids was made in Clarke and Ruedemann's *Monograph on the Eurypterida of New York* (**39**). While the work has to do mainly with the description of species and the study of larval stages and of the anatomy, leading to fuller knowledge of the ontogeny and phylogeny of the eurypterids as well as their taxonomic relations, still the authors have given some attention to the question of the bionomy (**39**, 96–113), coming to the following conclusions:

"Summarizing these data we conclude that the eurypterids lived in the sea from Cambric to Siluric time. They had then become less sensitive to changes, positive and negative, in the salinity of the water. In fact they seem to have thrived best under conditions of life that excluded most other marine groups of animals, that is, in the marginal, more or less inclosed marine lagoons, accompanied by estuaries receiving delta-forming terrestrial drainage, with prevailing arid or sub-arid climate, the waters being in some places more than normally briny, in others having less than normal salinity. In other words they were *euryhaline* or able to live in both salt and brackish water.

"Their adaptation to such conditions is paralleled today by such crustaceans as Apus and Artemia which not only thrive under rapid diminution of normal salinity but, by means of strongly protected eggs, even survive salt pan conditions which end in complete desiccation, as shown by their well known occurrence in desert lakes. The usual associates of the Siluric eurypterids are peculiar crustaceans whose nature emphasizes the reference above made. They are phyllocarids and ostracods and members of the strange family Hemiaspidae (Neolimulus, Bunodes, Hemiaspis, Pseudoniscus). This congeries of peculiar crustaceans seems to constitute a fauna especially adapted to, and therefore highly characteristic of, lagoon and estuary conditions.

"Thus while the earlier eurypterids were marine and their climacteric fauna euryhaline; their later habit throughout the Devonic and Carbonic led them finally into the fresh water.

"The succession of habitats is hence, according to our evidence, the reverse of that suggested by Chamberlin's hypothesis noted at the beginning of this discussion" (**39**, 112, 113).

In 1913 appeared the first extensive discussion of the habitat of the eurypterids in a paper entitled "Early Palaeozoic Delta Deposits of North America" by Professor Grabau, in which he brings forward arguments for the fluviatile habitat of these merostomes in the Ordovicic and Siluric of North America, and he includes a summary of the distribution and occurrence of the eurypterids by myself, reviewing the evidence and coming to the conclusion that the eurypterids were river-living at least during the two periods mentioned. The significance of the occurrences in the Pittsford, Shawangunk, and Bertie are discussed especially.

At the end of the same year Grabau's *Principles of Stratigraphy* was published. In Chapter XXVIII on the "Bionomic Characteristics of Plants and Animals" and elsewhere in the book the eurypterids are spoken of as fluviatile organisms as indicated by their distribution, faunal associates and mode of occurrence. A single statement taken from this book will show the position which Grabau holds. ". . . . The early remains of fish as of eurypterids are not found in normal marine deposits, but in those which are at least open to the suspicion that they are formed by rivers or at least at the mouths of rivers, while the best preserved remains, and the most abundantly represented in the Palaeozoic, are found in river flood-plain deposits and in deltas" (**87**, 989). For further references on this subject in the *Principles* see pp. 377, 425, 945, 950, 1029, 1030.

This gives us, then, the last word on the subject up to the present time. Looking over the opinions which have been recorded in the preceding pages, one is struck with the diversity of conclusions arrived at by our greatest American geologists and by not a few of those of Europe. From 1818, when the first Eurypterus was found, though it was not described as such till 1825, down to the end of the century, it was practically a universal opinion that the eurypterids had been denizens of the sea. The species were described along with marine forms and were considered to have been marine also. The study of the taxonomic position of the Eurypterida, showing always more and more clearly their close relationship to the modern Kingcrab, Limulus, gave an added reason for assuming a marine habitat for the fossil forms. With the beginning of the present century came the awakening of geologists and paleontologists to the fact that perhaps these extinct Merostomata had not always lived in the sea, that they may even never have known marine conditions. The current opinion now is that the eurypterids lived in the sea from Pre-Cambric time through the Ordovicic. During the Siluric they gradually became adapted to brackish and fresh-water conditions, living in estuaries and lagoons in the Devonic and becoming entirely fresh-water habitants in the Mississippic, Carbonic and Permic. Grabau is the only staunch advocate of the non-marine habitat even from the earliest times, though Chamberlin, to be sure, has argued such a possibility, but his discussion is purely philosophical, and while interesting and full of suggestive ideas, it is, nevertheless, unsupported by the evidence necessary for definite proof of his theory.

In attacking this problem the most important thing to determine is whether the Eurypterida began their existence in the sea or in the land waters, and under what conditions they lived in pre-Devonic time, for after that, it is now generally conceded, they lived in terrestrial waters.

CHAPTER III

The Bionomy of the Eurypterid Faunas

INTRODUCTION

In the first chapter I confined myself to facts which consisted of observations made in the field or the laboratory by students of the rocks and of the faunas. Such facts covered data on the geological and geographical distribution of the eurypterids; in the second chapter I gave a resumé of the opinions which have been held by various writers in regard to the habitat of the eurypterids; the remainder of the paper will be devoted to the contemplation of the recorded facts whose interpretation will be undertaken in the light of principles recognized by the school of philosophical geologists. For this reason, I shall in nearly all cases use the deductive method of inquiry, establishing the general principles which may then be applied to the particular case in hand. It is evident, then, that before we can begin to adduce proofs favoring one mode of life or another for the eurypterids, we must have a good classification of habitats in which each type is clearly defined, and we must determine at the very outset whether there are any criteria which may be recognized in the rocks as absolutely diagnostic of the habitats of the past. In so far as deposits in the sea and on the land have received any consideration at all, distinctions have mainly been drawn on the physical characters of the sediments; but I believe that much more accurate and far reaching results are to be obtained from the study of the fossil faunas. These may be investigated from two points of view, either the *chorological*, or the *bionomic;* and besides these, there is yet a third line of approach, namely the *geological*, in which the physical characters and lithogenesis of the sediments, together with the correlation of synchronous deposits constitute the elements. These three lines of investigation deal with three, for the most part mutually independent groups of facts and I am convinced that any one will yield sufficient evidence to determine the nature of any past habitat. In this chapter I shall deal with the bionomic characteristics of modern habitats, and shall give the criteria for recognizing ancient ones, concluding with the special case of the bionomy of the eurypterids. The following chapter will be devoted to the geological evidence regarding the habitats, while I shall defer until the fifth chapter the chorological evidence which is more conveniently discussed with the geological occurrences in mind. In considering the habitats, we may confine ourselves to those which are aqueous, since certain anatomical features, such as the nature of the cephalothoracic appendages and the presence of branchiae on the abdominal appendages, establish beyond a doubt the fact that the eurypterids lived in the water and not on the land, as do their near relatives the scorpions.

Before attempting to draw conclusions about the conditions under which the Eurypterida must have lived, it is necessary to have in mind the physical and faunal characteristics of the various types of habitats. Since these characteristics have never, so far as the writer knows, been discussed at length, I shall here state some of the results of an extended study of aqueous habitats which in time will be published as a separate paper.[1]

CLASSIFICATION OF RECENT AQUEOUS HABITATS

The most natural and fundamental characteristic which can be recognized in classifying aquatic bionomic realms is salinity, on which basis it is readily seen that there are only two original habitats: (1) marine, (2) terrestrial fresh water. Animals living either in marine or in fresh waters may become adapted to water which is of a salinity intermediate between the other two and generally designated "brackish," or to a salinity greater than that of normal marine waters. Thus to the two original types of habitat may be added two others: (3) brackish water, and (4) super-saline water, which are never original habitats. By this is meant that, minor variations excepted, no aquatic forms ever originate in the brackish water of estuaries, lagoons, cut-off arms of the sea, or interior basins, or in the super-saline waters of lakes. (This will be demonstrated below, pp. 73, 76, 77.) That this should be the case is due to the evanescent character of such water bodies. It is, of course, conceivable that a body of this type, long persistent, might be peopled from the land or from another aqueous realm and that such a fauna might be specialized. To these principal types may be added certain minor ones, giving seven in all. In the following table are given the salinity types, and with them what seems to be the best salinity ranges. It is not of importance here to go into the reasons for the making of the limits, but it may be said that they are based on a large number of typical examples in each case. The various realms may be secondarily grouped according to occurrence, as marine and terrestrial. In this latter group, two further subdivisions may be made according to mobility: the *courant* and the *static* waters. I propose the term courant for all terrestrial waters which are constantly moving in a given direction, as do the rivers. The following table brings out these points; of which further discussion will not be given in this paper.

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[1] Some parts of the following classifications were presented by the writer at the 1914 meeting of the Paleontological Society of America.

CLASSIFICATION OF AQUEOUS BIONOMIC REALMS ACCORDING TO SALINITY[2]

CLASSIFICATION		SELECTED EXAMPLES					
Type of Salinity	Range in Permille	Marine		Courant		Static	
		Examples	Per-mille	Examples	Per-mille	Examples	Per-mille
I. Fresh....	0.0–0.2			Amazon River at Obidos Rhine at Cologne	0.037 0.178	Lake Erie	0.134
II. Subbrackish.....	0.2–1.0			Vistula near Culm Arkansas R.	0.201 0.794	Laacher See Humboldt Lake	0.218 0.928
III. Brackish..	1.0–10.0	Baltic Sea	7.80	Salt River Rio de los Papagayos	1.234 9.185	Palic Lake Lake Biljo	2.215 8.800
IV. Superbrackish.	10.0–20.0	Sea of Azov Black Sea	10.60 18.30			Caspian Sea (in 1878)	12.940
V. Subsaline.	20.0–30.0	Arctic Ocean Hudson Bay	25.50 26.00			Van Lake	22.601
VI. Saline....	30.0–40.0	Behring Sea Atlantic Ocean Red Sea	30.30 35.37 38.80			Albert Lake	39.772
VII. Supersaline...	40.0–289 plus					Tinetz Lake	289.000

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[2] The examples and salinities in this table are taken from the tables compiled from various sources by Professor Grabau, and given in the "Principles of Stratigraphy" (87). The classification is new.

RECENT AQUATIC FAUNAS

Having established what seem to be fairly accurate limits for the ranges in salinity in all of the waters on the surface of the earth, it becomes possible to study the faunas of these different realms, for the type of life in any given water body is more dependent upon the salinity than upon any other physical factor with the exception of extremes of temperature. The absolute necessity of studying recent faunas with particular attention to the types of organisms represented, and to the numbers of species and of individuals, has not been realized sufficiently in the past. The habitats of fossil faunas cannot be determined without a knowledge, an intimate knowledge, of the habitats of recent faunas. To be sure, there is little doubt about the kinds of organisms which make up a typical marine fauna; in many cases, too, there may be no difficulty in recognizing a fresh water (especially lake) fauna, but there is an undoubted haziness and lack of precision in all ideas connected with brackish waters and with the faunas thereof. When a given fossil fauna has shown certain peculiar characteristics, such, for instance, as a complete or almost complete absence of molluscan representatives or when the fauna has been confined to one or two classes of organisms, the custom has been and still is to say that the organisms lived in brackish water. It is, thus, necessary to determine the nature of recent faunas which are characteristic of the various bionomic realms, in order that we may, not without a fair degree of certainty, establish the criteria for determining the faunal nature of the habitats of the past.

Marine. The marine fauna is always large and varied, comprising, typically, representatives from each taxonomic division among the invertebrates. Not only are there a large number of genera and species, but nearly all phyla are represented. For the mollusca alone the number of genera in a given region may run up into the hundreds and that of the species may be considerably over a thousand. The figures apply especially to the littoral zone, that belt along all coasts which is most favorable to life. There light penetrates to the bottom, the food supply is abundant, and varying substrata are available to suit the needs of different organisms. This zone, extending from high water approximately to the two hundred fathom line, is the one of greatest geologic interest because nearly all of the marine formations of the past were littoral; unequivocal abyssal deposits being very rare. Since practically all of the invertebrate organisms of this prolific littoral marine fauna are protected either by shells or by exoskeletons, each individual that dies leaves its record behind in some hard part which falls to the bottom when the animal dies, or else soon comes to rest there, where it is buried by sand or mud. Not only are the remains of the animals which lived in the littoral zone of the sea preserved in the deposits forming there, but many derelicts, dead or alive, are washed in from the land and the rivers and we have a phenomenon observable in no other bionomic realm, namely, the commingling in one life district of the remains of organisms from all the other districts. During storms, terrestrial animals are drowned in the torrential floods, trees and other vegetation are carried away in the undermining of the banks, and these, together with the remains of fluviatile organisms and even with the living forms which cannot resist the strength of the current, are all carried out to sea to be dropped and there entombed with the remains of marine organisms. In tropical and semi-arid regions such mingling of terrestrial and marine forms is the common, not the unusual, thing. Darwin has called attention to many such cases in his *Voyage of the Beagle*, where he describes the great drought which occurred between the years 1827 and 1832 in Buenos Ayres, South America, when the birds and animals died by the thousand, the vegetation became withered and parched, and the dry winds swept over the desolate waste of land desiccated and dusty. The large rivers shrivelled, the small ones disappeared altogether; and where a little water still remained in the broader courses, it became highly saline, bringing death to the animals who drank. Herds of cattle rushed into the river, crazed by thirst, and there perished from the salt water and because they were too weak to climb up the banks again. Following this drought which lasted five years, came the rainy season and torrential floods. "Hence it is almost certain," Darwin concludes, "that some thousands of the skeletons were buried by the deposits of the very next year" (**48**, 127). Not only in semi-arid climates where torrential floods are active, but even in pluvial climates are terrestrial and fluviatile organisms carried out to the littoral zone of the sea, where they are buried in the delta deposits together with marine shells and tests. Thus, terrestrial vertebrate remains have been found in the deltas of the Ganges and Zambesi, the bones of recent antelope, buffalo, lion, hippopotamus and other mammals having been recorded; in the Po delta arthropods occur with lignites. Such terrestrial relics are by no means confined to deltas or river flood plains, but are found along all coasts even where no rivers enter as well as at considerable distances from shore beyond the debouchures.

Walther makes mention of the occurrence of great rafts of trees off the mouth of the Congo, 450 km. from shore, some of these interlocking tree islands being 100 m. across. Agassiz likewise has noted in the Caribbean Sea, Helix, leaves, and other land organisms dredged from a depth of 1000 to 2000 fathoms, which is far beyond the littoral zone.

Thus we must conclude that in the marine waters, and especially in the littoral zone, there is not only an abundance of invertebrate organisms of nearly all phyla, but there are stragglers from other realms; insects and plants are blown out to sea, while terrestrial animals and vegetal remains, together with fluviatile organisms, are carried along by the rivers, all at length being entombed in the marine sediments with the hard parts of the organisms which lived and died in the sea. In such cases we should expect to find the fluviatile and terrestrial remains shattered and worn on account of being transported oftentimes for a considerable distance, and usually subject to partial destruction by the débris which the rivers carry. At any rate, it is apparent that it is customary, not anomalous, for the remains of terrestrial and marine organisms to occur together.

FRESH WATER. The fresh-water faunas of rivers and lakes, on the other hand, present quite different features. While the number of individuals in a given river or lake may indeed be large, the number of genera and species is very small as compared with those in the neighboring marine waters. Furthermore, there are only a few large classes abundantly represented, such as the fish, molluscs, and protozoa, while all of the other classes, so well represented in marine waters, are in given rivers or lakes represented often by a single species only, or by none at all. Three comparative sets of figures for the molluscs will serve to illustrate how small the number of genera and species is in fresh water when compared with those in marine waters at approximately the same latitude.

Table showing number of Genera and Species of Mollusca in Various Bionomic Realms

LOCALITY	NIAGARA RIVER	SAGINAW BAY	WOODS HOLE, MASS.	MASS. COAST
	permille	*permille*	*permille*	*permille*
Salinity	0.134	0.105	30.0	35.0
Genera	15	23	133	175
Species	24	93	203	466

The complete known invertebrate fauna from Woods Hole numbers 1286 species, while in the open marine, somewhat more saline waters, the number is even larger (**270**, 85).

Brackish Water. In dealing with the brackish-water faunas many difficulties are encountered, because not very much work has been done in connection with the various brackish-water bodies and it is thus hard to obtain data. Two examples, the Baltic Sea, and the Severn Estuary will be discussed.

The Baltic Sea. One of the best known of brackish-water bodies is the Baltic, which, though it cannot be considered an estuary may yet serve admirably to demonstrate the changes in fauna which occur with changes of salinity. The Baltic lacks the tides which are characteristic in estuaries and therefore does not exhibit the pronounced changes from fresh to salt water twice a day. It is more static and shows in a large way the responses of the fauna to salinity. The North Sea has a normal marine salinity of 35.00 permille, which decreases steadily eastward in the Baltic. In the Skager Rak it is 34 permille, off Skagen, the northeasternmost point of Denmark, it is 30 permille, in the Kattegat 22, and in the Bay of Kiel 20 permille. Throughout the southern part of the Baltic, from the "Scheren," at the mouth of the Gulf of Finland, to Bornholm the salinity is from 7 to 8 permille at the surface and does not vary greatly in the depths. For instance, in the deepest part of the Baltic off the Island of Gotland the salinity is only 12 permille, and in the Bay of Danzig, which shows a yearly average of 7.22 permille at the surface, it is only 11.66 permille (average) at the depth of 105 meters. In the Bay of Riga the salinity is 6 permille, in the southern part of the Gulf of Bothnia it is 4 permille and gradually diminishes until the water is entirely fresh. Corresponding to these changes in salinity are certain very definite changes in the fauna (Fig. 1).

As the salinity decreases from that of normal sea water, 35.00 permille, the fauna changes from a typical marine one to one in which only certain groups are represented and finally to an entirely fresh-water fauna. Each phylum shows this change; Pouchet and de Guerne have reported that a truly marine crustacean fauna extends into the Baltic as far as Kalmar Sound, between Öland and Sweden, but that beyond this point the marine species are gradually replaced by certain euryhaline forms and finally by the fresh-water ones until at the head of the Gulf of Finland the planktonic crustacean fauna is made up entirely of fresh-water types. Thus *Evadne nordmanni* is very abundant in the western part of the Baltic, but is replaced eastward by *Bosmina longirostris;* another abundant euryhaline form is *Podon intermedius.* The replacing fresh water types are such as *Cyclops quadricornis*, *Daphnella brachyura*, *Daphnia quadrangula* and *Bosmina longirostris* (Pouchet and de Guerne, **223,** 919, 920). The mollusca show a similar change, the Littorina species, for instance, being replaced by Limnæa, while along the coast where the salinity is low both of these forms live together, and there also *Neritina fluviatilis*, a river form is found.

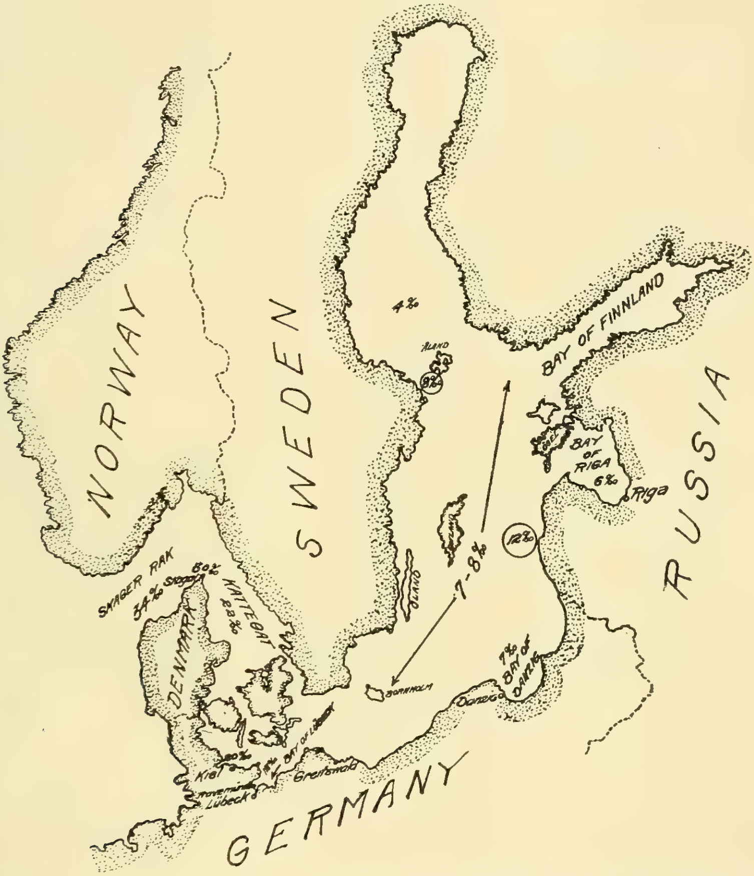
NORWAY
SWEDEN
4‰
ALAND
9‰
BAY OF FINNLAND
BAY OF RIGA 6‰
Riga
RUSSIA
12‰
7-8‰
OLAND
SKAGER RAK
34‰
Skagen
80‰
KATTEGAT
28‰
DENMARK
BORNHOLM
7‰ BAY of DANZIG
Danzig
20‰
BAY OF LÜBECK
Kiel
Lübeck
Greifswald
GERMANY

FIG. 1. SKETCH MAP OF BALTIC SHOWING PERMILLAGE VARIATIONS IN SALINITY

A second change which takes place in the Baltic fauna and which may be correlated with the variation in salinity, is that the stenohaline forms of the marine fauna disappear altogether, while the euryhaline ones become dwarfed. Thus, the common cockle shell, *Cardium edule*, in the North Sea, of normal marine salinity, is the size of a small apple, at Stockholm, where the salinity is below 10 permille, the shell in the deeper, more saline water is only as large as a walnut and is even smaller along shore where the water is fresher. At Königsberg, with the decreasing salinity, the size reaches that of a hazel nut, whereas at Reval, it is only the size of a pea. In like manner, *Mytilus edulis*, which is 8 to 9 cm. long at Kiel is only 3 to 4 cm. long at Gotland. The fish and worms also show dwarfing.

A third point to be noted is that the fauna decreases very rapidly in the number of species which occur. Karl Möbius in his report on the faunal survey in the Baltic Sea made by the Pommerania, states that:

"The total number of observed invertebrate animals amounts to about 200 species, not including the infusoria and crinoids.

"We have found scarcely one-fifth of these in the great eastern basin of the Baltic which begins between Rügen and the southern extremity of Sweden" (**182**, 277). The following table shows the distribution for the invertebrates. The numbers given for the Baltic as a whole should be compared with those given for Kiel. In this latter bay the conditions are not so different from those in the open

Comparative Number of Species of Invertebrates in the Baltic, etc.

PHYLA	WATERS AROUND GREAT BRITAIN	BALTIC AS A WHOLE	BAY OF KIEL	BAY OF TRAVEMUNDE
	35 permille	7.8 permille	20 permille	12 permille
Protozoa	69			
Porifera	42	7	3	3
Coelenterata	98	28	24	8
Echinodermata	48	6	5	2
Vermes	101	68	50	26
Bryozoa		11	8	5
Crustacea		50	36	19
Mollusca	682	68	64	40
Tunicata		5	4	4
Total	1040 (+)	243	194	107

sea as to have affected the fauna very markedly, but it will be noted that marine types must predominate in the fauna of the Baltic, as a whole, since for none of the phyla are the numbers much greater than they are at Kiel, where the fauna is wholly marine.

Perhaps the most significant fact brought out, is that the marine forms which are found in the Baltic, though they may be dwarfed or otherwise modified, are not different specifically from the marine forms found along the coasts of Great Britain, nor do the fresh-water forms differ from those found in the rivers emptying into the Baltic, or those in the neighboring fresh-water bodies. Thus it is established that in a brackish-water body of the nature of the Baltic the fauna is due to the mingling of modified marine and of modified fresh-water, that is, river forms. Only the more euryhaline marine species survive and these may in a given estuary give rise to a fauna which we may designate as a "brackish-water fauna." It will consist of forms derived in the manner just described, and these forms may become adapted to the peculiar temperature and salinity conditions prevailing in the given estuary. Thus, new mutations, varieties, and occasionally species may arise, but seldom a new genus and never a whole class of organisms. It is only the smaller taxonomic divisions which are affected. Furthermore, a "brackish-water fauna" in any estuary is always ephemeral, for the estuary is of short duration, geologically speaking.

The Severn Estuary. While the Baltic serves to show on a large scale what happens to a marine fauna which is gradually subjected to fresher and fresher water until it passes through brackish conditions to entirely fresh ones, there is another type of brackish water, the estuary, which is often said to have a fauna of its own. An estuary may be defined as the drowned lower portion of a river in which twice daily there is a change in the water from fresh to marine and back again as the tide comes in and goes out. On account of the tidal scour and thorough mixing of the marine and the inflowing river water, the brackish portion will not be very large. The Severn, on the west coast of England, is a very typical estuary, having the long, slowly broadening form toward the sea. There are a number of tributaries with their respective estuaries, so that on the whole the Severn may be considered characteristic. It is well known that muds are the dominant sediments, not only in the main tidal channel far out to sea, but also in all of the tributary channels. Professor W. J. Sollas has made a careful study of these muds in order to determine their distribution, origin and their included organic remains. In regard to the origin he says: "The rivers which discharge into the Severn estuary, draining, as they do, a catchment basin of 9193 square miles, are the chief sources of supply" (**264,** 611). A source of secondary, but by no means slight importance is the sea, which has worn off material from the cliffs and which has carried muds into the Severn. As Sollas has fully explained, though the details cannot here be given, a small part of the silt which is brought down by the rivers may be deposited in the estuaries themselves, but the greater portion is carried seaward, "so that the final resting-place of the sediment of the Severn is situated some distance out to sea." A microscopic examination of the muds from a large number of localities on both sides of the Severn and along its tributaries revealed the following organic remains: "Coccoliths and rarely coccospheres, both of the ordinary cyatholith type so common in adjacent seas and in the Atlantic ooze; Foraminifera such as Miliola, Textularia, *Nonionina crassula*, *Polystomella umbilicata*, Rotalia sp., Spirillina sp. . . . spicules of Alcyonaria rarely; fragments of Echinoderm skeletons and minute spines: and triradiate spicules of Calcisponges, probably derived from *Sycandra ciliata* and *S. compressa*. The siliceous constituents are chiefly sponge-spicules, very rarely Radiolaria, and a variable quantity of Diatoms." The remarkable feature about these remains is that they are all marine, and yet they sometimes occur on the banks of the rivers at a great distance from truly marine waters. Moreover, the remains which are found are of organisms not living within many miles of the places where they occur, for Sollas has carried out a careful investigation of the fauna along the coast. He says: "Sponges do not grow anywhere so near Bristol on this side of the Channel as Portishead and Weston; Lynton, which is about 60 miles away, is the nearest possible locality; while Ilfracombe, about 15 miles further west, is well known as a rich collecting ground for both siliceous and calcareous sponges, and a host of other marine forms, including sea urchins and starfish, which might well furnish the echinoderm network and spines so frequent in the ooze. On the other side of the channel one would need to go to Bridgend before meeting with much in the way of shore life, and I doubt, after a hasty visit to that locality, whether much would be found there; a good deal farther west is Tenby, and no naturalist needs to be informed of the luxuriant growth of all kinds of marine animals, including sponges to be met with there" (**264,** 619). Sollas clearly shows that the remarkable distribution of marine remains far up the estuaries is due to the strong tidal current which brings the débis of organisms living along shore in the more open waters. This current rushes up the Severn at the rate of 6 to 12 miles an hour and it distributes the muds and microscopic organic remains as far north as Gloucester and to every estuary opening into the Severn. "On these shores, so remote from their source, some of these organic fragments find a permanent resting place, and thus far inland we discover along a river bank deposits, containing marine remains. But those which stay are few compared to those which are washed away again and carried out to sea, there to be deposited in marine mud-banks, probably not far from their original home" (**264**, 620). Just a few miles above the points at which the marine organic remains were found, the muds were examined and every sample showed abundant sponge-spicules, but these all proved to be of the fluviatile species, *Spongilla fluviatilis*, and none of the marine forms were found. This is the fauna of the recent muds, but a section through the older alluvial deposits which have a maximum thickness of 50 feet, shows that conditions have been much the same for a long time, and that there has been a constant alternation of conditions, first marine, then terrestrial, with the formation of peat beds. Wherever the estuarine sands and muds are washed over the peat beds a similar fauna, dominantly marine, though with fresh-water forms intermixed is found. The section is as follows in descending order:

Zone 1. Upper clay.
  a. More sandy zone, 5 to 7 feet
  b. More argillaceous zone, with disseminated vegetable matter 7 to 8 feet,
  Upper peat, 1 to 2 feet, 6 inches.
Zone 2. Lower clay
  Lower peat, 1 to 4 feet
Zone 3. Sands and mud
  Gravel
  Triassic sandstones

The deposits in the Severn estuary indicate a gradual subsidence of the land or advance of the sea. Both the upper and lower clay are blue and usually highly fossiliferous. In some sections a few feet will show an abundance of Foraminifera followed by several feet containing vegetal matter. In one section in which no peat was exposed the shaft sank through 39 feet of clay and then struck a marl bed one foot thick containing Limnæa, Planorbis, *Scrobicularia piperata, Cardium edule,* diatoms and Chara.

Yet another illustration of the nature of the faunas of estuaries may be found in the complete lists given in Verrill and Smith's invaluable report on the Invertebrate Animals of Vineyard Sound and Adjacent Waters (**280**). The fauna as there recorded from the sandy shores and bottoms of estuaries of the southern New England coast includes: Insects, Crustacea, Annelids, Gastropods, Pelecypods and Nemerteans all of which, with the exception of the last group, are represented by eight or more species (**280**, 170, 171); from the bottoms of sheltered estuaries, ponds, and harbors the following fauna is noted as characteristic:

Insects (4 species), Crustacea (30 sp.), Annelids (13 sp.),
Nemerteans (2 sp.), Nematodes (2 sp.), Gastropods (15 sp.),
Pelecypods (18 sp.) (Verrill and Smith **280**, 176–178.) The study of the brackish water bodies in the region just mentioned has shown that the animal life is very abundant and that the number of species found, while not so great as in the open sea, is still fairly large. Particularly is it to be noted that the species which do occur are abundantly represented and are remarkable for their hardiness and ability to live under widely varying conditions. A few of the species are restricted to the brackish water, but by far the largest number are able to live in pure sea water.

SUMMARY OF FAUNAL CRITERIA FOR DETERMINING THE TYPE OF AN AQUEOUS HABITAT

The chief faunal characteristics of recent aquatic bionomic realms may now be summarized.

1. The typical marine fauna is widespread, large, with an abundant representation in individuals, species, and genera from practically all of the phyla of the invertebrate animal kingdom. The various lithologic facies have their peculiar faunules, but each one of these contains types from all or nearly all of the phyla, while many cosmopolitan species, particularly among the pelagic plankton and nekton are entirely uninfluenced by the substratum and their remains consequently will be found with those of forms restricted to particular facies. Furthermore, terrestrial and fluviatile organisms will quite frequently be found in the marine fauna, having been transported

there alive or dead, and their hard parts will be preserved with those of the typical marine species.

2. The number of genera and species in fresh water is as a rule very much smaller than that in the neighboring sea, although the number of individuals may be nearly as large. Entire classes of organisms are wanting, while other classes are represented by only a few genera and species. Fresh water organisms are distributed by rivers and are found living in lakes and lagoons on the subaërial portions of deltas, in lakes, playas and more rarely epicontinental seas, all of which water bodies are geologically short lived.

3. Brackish waters may be considered under two types:

(a) The brackish waters or land-locked epicontinental seas such as the Baltic show a range in salinity from that of normal sea water to that of the rivers which empty into such water bodies. The fauna is made up of a modified marine and a modified fresh-water fauna, and always has its nearest relatives in the open sea, on the one hand, and in the rivers and connecting fresh-water lakes, on the other. Since the species contributed by the marine waters are so much more numerous than those contributed by the rivers, the greater number of the species in the brackish water will be related to marine forms.

(b) The brackish waters of estuaries are not stable enough to have a fauna which may be considered endemic. The marine fauna lives along shore and in the waters not too much disturbed by the tidal current, but the organic remains found in the estuaries are marine. Moreover, along the coasts affected by the deposition of the tidal muds, no organisms live and it is only many miles away from the estuary proper that the marine forms are found whose hard parts, carried by the tidal currents and in time comminuted, finally come to settle on the floors of the estuaries and on the river banks. These hard parts are carried up the estuaries as far as the tidal current is felt and it is only above this point that the fresh water forms are found. In the very small area between the purely fresh and the dominantly marine waters is the brackish-water area in which there may be a small mixed fauna.

APPLICATION TO THE PAST

Armed now with a considerable wealth of facts drawn from the present, we may turn to the past in an attempt to set forth any available criteria which may be used in determining the nature of a given habitat.

Marine Deposits and Faunas. Sediments which accumulated in the open marine waters at all times, subsequent at least to the Pre-Cambric, have been found to contain a rich and varied fauna in which were represented all of the larger groups of the invertebrate animal kingdom which are recognized today. One need only mention the prolific faunas of the Cambric of St. John, New Brunswick, and of British Columbia, the Trenton of New York, the Niagaran of New York and elsewhere, the Hamilton of the eastern United States, the Muschelkalk and Upper Jura of Germany, the Upper Cretacic of the middle and north of Europe, and the Eocenic of France and England. Not only is the number of individual fossils great, represented by many species, but these species are scattered through many phyla, just as at the present time the organisms in the oceans are numerous and diversified, no one class reigning to the complete exclusion of others. This does not mean that we shall find the same distribution according to phyla in the past, but we do know that it will be diverse. The vertebrates, for instance, cannot be of importance in faunas until their evolution has had time to take place, and thus they are not found represented in the rocks in abundance before the Devonic. Thus the important phylum of Pisces find no, or only rare representation in the early Palæozoic rocks; but, on the other hand, there were the Crustacea throughout the Palæozoic, especially the trilobites, which became extinct at the end of that period. And so one might nicely appose the phyla, or more often orders or families, which were represented in the past, but are not now, and in this way we would see that the past, though different from, was similar to the present, and that Palæozoic seas, even the earliest ones, lacked not in life and in the diversity thereof.

The very nature of marine waters, their continuity and great extent, suggests migration and wide distribution through currents. Barriers there were, of course, both by land masses and ocean currents, streams of cold water, and so forth, but, nevertheless, we know that migration along the coasts of the continents took place as it does today and that many species or at least genera spread throughout all of the oceans, for if we did not believe in the forces of migration and dispersal we would not have laid down the laws of correlation which are universally recognized. In no way, then, can a typical marine fauna remain bottled up in one place, with none of its members escaping to adjacent waters; such a thing cannot happen today and it is not reasonable to suppose that it happened in any geological period in the past.

FLUVIATILE DEPOSITS AND FAUNAS. The importance of sediments containing river faunas has not heretofore been realized, nor have such sediments and their characteristics been dwelt upon by most geologists. Grabau has been the staunchest advocate of the fluviatile origin of many deposits both in this country and Europe, but has usually stood alone in his interpretations. In his paper on "Early Palæozoic Delta Deposits of North America" he has described in great detail a large number of delta deposits occurring in the Ordovicic and Siluric and has shown what are the characteristics physical and faunal of such deposits. Barrell has likewise made a number of contributions to the study of fossil delta deposits with especial emphasis on their physical characteristics, and on the climatic factors controlling sedimentation.

It is a matter of difficulty to determine much about rivers of older geological periods, because the river channels are seldom preserved, especially in the Palæozoic, and when found are visible, usually only in section and cannot be traced along the surface. Flood plain and delta deposits are almost the only records of their presence left by ancient rivers. It is not to be expected, however, that such deposits will be without fossils any more than similar deposits today are. Rivers carry large amounts of detritus varying in grain from fine muds, a fraction of a millimeter in diameter, to bowlders often several feet across, though these coarser elements are more likely to be carried by torrential or mountain streams than in the larger rivers. In a pluvial climate this load is brought into lakes or to the ocean and there deposited; in an arid climate it is spread out on interior plains or in basins in the form of alluvial fans or dry deltas. Since the lithological characteristics of deltas and flood plains are often of great assistance in the recognition of fossil deposits of this type, it may not be amiss to say a few words about them here.

The sediments spread out by a river in its lower reaches are of two types: (a) those which form directly at the mouth and are spread out in front of it into the sea, and (b) those which are spread out laterally either over the subaërial portion of the delta or along the floodplain and over the neighboring lowlands throughout the lower portions of the river. These are the fine mud deposits of which we see such splendid examples in the case of the Nile and Mississippi deltas. The deposits in the Nile delta are thus described: "At low water these are visible in the steep banks which then rise 8 to 10 meters above water level. The hardened Nile mud forms a series of horizontal beds varying in thickness from a few inches to several feet, and looks more like an ancient stratified series than a modern deposit. The material of the Nile mud is a more or less uniformly fine-grained one, the size of the grains varying from $\frac{1}{13}$ to $\frac{1}{100}$ mm., rarely reaching to $\frac{1}{10}$ mm. in size" (Grabau, **87,** 614). The Mississippi delta is spread out in the remarkable bird-foot form and the whole of its lower part is covered with a network of distributaries which often empty into large fresh-water lakes. In these lakes and over all the interstream areas the fine muds are deposited. They contain shells of fresh-water molluscs and much driftwood, which is often united into floating rafts.

In the portions of the delta nearer the sea, fresh-water and marine organisms are both found, not intermingled, however, but in separate layers, depending upon whether beds were deposited in the sea or by the streams above the sea. Thus a bed with fresh-water shells and lignite is often intercalated between beds with marine remains, giving evidence of the shifting conditions of deposition in deltas where streams continually change their channels and where consequently the areas of terrestrial deposition are shifted, while the sea advances in the interfluve areas and a wedge of marine deposits is formed.

Here a few details in regard to the nature of the Indo-Gangetic delta will give a good idea of what types of sediments and organic remains are to be expected. Lyell states that "No substance so coarse as gravel occurs in any part of the delta of the Ganges and Brampootra, nor nearer the sea than 400 miles (**154,** 280). A boring to a depth of 481 feet made near Calcutta showed below the surface soil, at the top of the first 120 feet of the boring, a stiff blue clay succeeded downwards by a sandy clay and this in turn by a peat bed. A nodular limestone, the kankar, of fresh-water origin, was encountered.[3] Below the first 120 feet there were found various beds "consisting of clay, marl, and friable sandstone with kankar here and there intermixed, [while] no organic remains of a decidedly marine origin were met with . . . . The only fossils obtained in a recognizable state were of a fluviatile or terrestrial character. Thus, at the depth of 350 feet the bony shell of a tortoise, or Trionyx, a fresh-water genus, was found in sand, resembling the living species of Bengal . . . . At the depth of 380 feet, clay with fragments of lacustrine shells was incumbent on what appears clearly to have been another "dirt-bed," or stratum of decayed wood . . . .

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[3] For description of kankar, see Grabau's *Principles of Stratigraphy*, 87, pp. 586, 719.

At a depth of about 400 feet below the surface, an abrupt change was observed in the character of the strata, which were composed in great part of sand, shingle, and boulders, the only fossils observed being the vertebrae of a crocodile, shell of a Trionyx, and fragments of wood very little altered, and similar to that buried in beds far above" (**154**, 281). This boring was very evidently through the subaërial portion of the delta, which was deposited at a time when the land stood higher and when, probably, hilly areas now removed by erosion or covered by deposits supplied coarser material near the seashore. The variability in the types of deposits is shown and it is seen that neither nodular limestones or conglomerates imply the presence of the sea for their formation. The sediments of the present delta are all fine-grained, the coarse deposits being found only at the foot of the mountains. Moreover, the fine sediments are carried far out to sea. "The sea, where the Ganges and Brahmapootra discharge their main stream at the flood season, only recovers its transparency at the distance of from 60 to 100 miles from the delta" (**154**, 279). In speaking of the Mississippi river Lyell says: "The prodigious quantity of wood annually drifted down by the Mississippi and its tributaries, is a subject of geological interest . . . . as illustrating the manner in which abundance of vegetable matter becomes, in the ordinary course of nature, imbedded in submarine and estuary deposits" (**154**, 268).

When the enormous transporting power of rivers is considered, when we think of the amount and variety of sediments together with terrestrial and fluviatile organic remains annually brought down to the sea by rivers there to be mixed with the marine sediments and the organisms living in the sea, we find it not so difficult to realize that the same phenomena happened in the past. The wonder would be if such intermingling had not taken place, and one must indeed be surprised to note how seldom it seems to have come to pass in the Palæozoic. Even admitting that land vegetation was mostly of a primitive, easily destructible, non-vascular nature in the Palæozoic, we still must marvel that so few fluviatile and terrestrial forms were carried out into marine deposits.

If the above characteristics are kept in mind it will not be difficult to formulate a certain number of criteria which may be used in recognizing a fossil delta or flood-plain deposit. That portion of the delta adjacent to the mouth of the river will be characterized by an alternation of marine and continental deposits, and these will be recognized in ancient deltas by a lithological and faunal interfingering. The silts brought down by the river will contain the remains of the river fauna, while the submarine deposits, be they sandstones, shales or limestones will contain a marine fauna. The two types of deposits as well as the two types of faunas, though they interfinger, will be of a distinct and recognizable character as a rule, and the nature of the faunas, in regard to numbers of individuals and species, will be recognized by the characteristics listed on page 77 above. The deposits on the subaërial portions of the delta and laterally in the flood-plain areas will consist of fine silts. Along the river banks the coarsest of the silts will be deposited and with them the heavier organic remains if there are any, such as the shells of molluscs. But with the finer silts periodically spread out at times of flood far to either side of the river, will be carried only the lightest materials, probably only plant remains and the exoskeletons of the various fluviatile crustaceous animals. Such organic remains may be carried out in great numbers, and if quickly buried will be excellently preserved in the fine muds. On the other hand, if they are carried a long distance, dropped and exposed to the air, and later perhaps picked up by some distributary and carried on again, the process being often repeated, they may be broken up, and when they finally come to rest and are buried, not a single complete organism will remain. Indeed, if in their final resting place they are exposed to the air for a long time and the mud on which they lie becomes sun-cracked, the fragments, drying up, may be blown for great distances, perhaps far inland or perhaps out to sea, coming to rest at last in regions far removed from those in which the organisms had lived and there amidst a strange fauna the remains may be entombed.[4] In the sediments such a history could be read, if in shales or waterlimes the only organic remains were those of light specific gravity. Of the invertebrates there would probably be some arthropods or insects; among the plants, leaves, algæ, reeds and grasses would be expected. Such a deposit would be difficult to correlate with a marine deposit, because it might contain none of the contemporaneous marine organisms. If, perchance, some of the river organisms or fragments of them had been blown or carried to sea, their remains could be entombed with the typical marine fauna and the age would thus be determinable. It is not unlikely, too, that stray molluscan shells might be blown from the shore inland, as they are today, and might come to rest in the very muds in which the river organisms were buried. Likewise, in the low-lying portions of the flood plain near the sea, occasional high tides or inundations, through the wearing away of sand-bars, might allow the salt water to enter, carrying some marine shells into those regions. Then the fossil fauna would show a large number of forms belonging mainly to one phylum, the arthopods, and occasional single specimens of members from other phyla. If the opposite conditions prevailed, and the fragments of the arthropods or their exoskeletons were blown to sea, then the fossil fauna would reveal many marine organisms, complete and well preserved, from all or nearly all of the invertebrate phyla, and occasional fragments of another group of organisms which were not well preserved and whose occurrence in such surroundings seemed anomalous.

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[4] In this connection it is interesting to record that the eurypterids of Oesel have such a thin test, that specimens exposed by the breaking of the rock are not uncommonly blown away by the wind.

BRACKISH-WATER AND ESTUARINE DEPOSITS AND FAUNAS. It has been shown that at the present time there is no such thing as a brackish-water fauna made up of classes of organisms different from those found in neighboring marine and fresh waters. It might be extremely difficult to recognize from the sediments and fossils that any fauna had lived in brackish water, because unless the salinity had been reduced so much that it was nearly that of fresh water the fauna would not appear to be very different from a typical marine one, except that it would be dwarfed and would contain few species. An estuarine fauna would likewise be difficult to recognize from the fossils. These would, however, be likely to be fragmentary, even comminuted to microscopic size, and larger forms would be found only in the sands and coarser deposits along shore and not in the estuarine deposits proper. It has been seen that the conditions in an estuary are not favorable for supporting life. The tidal scour, the churning up of the water, keeping the sediments constantly in suspension, the sudden change in salinity twice every day, are environmental factors not at all conducive to attract marine animals which can find more stable and beneficial conditions along the coast on both sides of the estuary. Thus, we saw that in the Severn the organisms whose comminuted remains were found in the muds lived many miles away in the quieter waters north and south of the estuary. In the geologic column we shall probably rarely be able to recognize estuarine deposits from the faunas, but if at all it will be from the nature of the sediments, their lithological characters and sources.

THE EURYPTERID FAUNAS AND ASSOCIATED ORGANISMS

In the following lists the eurypterid faunas of the various occurrences is given, as well as the organisms other than eurypterids which are found associated with them. No account is taken here of single occurrences or of the presence of a few fragments in normal marine faunas.

ORDOVICIC

Normanskill Fauna.

Eurypterids.

- Dolichopterus breviceps
- Eusarcus linguatus
- Eurypterus chadwicki
- Pterygotus ? nasutus
- P. normanskillensis
- Stylonurus modestus

Associated organisms. Seaweeds and graptolites.

- Rhombodictyon
- Climacograptus bicornis
- C. bicornis var. peltifer
- Cryptograptus tricornis
- Dicellograptus gurleyi

Schenectady Fauna.

Eurypterids:

- Dolichopterus frankfortensis
- D. latifrons
- Eurypterus ruedemanni
- E. pristinus
- E. ? stellatus
- Eusarcus ? longiceps
- E. triangulatus
- Hughmilleria shawangunk
- Pterygotus ? nasutus
- P. prolificus
- Stylonurus limbatus

Associated organisms.

- In sandy shales, seaweed, Sphenothallus latifolium
- In black shales, graptolites and trilobites
- Climacograptus bicornis
- Triarthrus becki

SILURIC

Earliest Lower Siluric (Ee$_1$.) Fauna of Bohemia.

Eurypterids.

- Eurypterus acrocephalus
- Pterygotus barrandei

P. beraunensis
P. bohemicus
P. nobilis
P. cf. problematicus

Graptolites.

Monograptus turriculatus
Other species

UPPER LOWER SILURIC (Ee_2) FAUNA OF BOHEMIA.

Eurypterids. (All very fragmentary.)

Pterygotus barrandei
P. beraunensis
P. blahai
P. bohemicus
P. fissus
P. kopaninensis
P. nobilis
P. cf. problematicus
Slimonia cf. acuminata

Associated fauna.

The typical and abundant Upper Siluric of Bohemia.

WENLOCK FAUNA OF PENTLAND HILLS, SCOTLAND.

Eurypterids.

Bembicosoma pomphicus
Drepanopterus bembicoides
Drepanopterus lobatus
Drepanopterus pentlandicus
Eurypterus conicus
Eurypterus cyclophthalmus
Eurypterus minor
Eurypterus scoticus
Eurypterus, 3 sp. und.
Slimonia dubia
Stylonurus elegans
Stylonurus macrophthalmus
S. ornatus

Scorpion—Palaeophonus loudonensis
Ceratiocarid—Dictyocaris ramsayi (Taxonomic position doubtful)
Sponge—Amphispongia sp.

In beds above or below eurypterid layers, the following fauna has been found:

Graptolites

Dictyonema venustum
D. (Chondrites) verisimile
Cyrtograptus murchisoni ?
Monograptus priodon
M. vomerinus

- *Coral*—Favosites sp.
- *Asteroidea*—Palasterina sp.
- *Crinoids*—fragments
- *Brachiopods*—
  - Lingula lewisi
  - L. symondsi
  - Strophomena walmstedti
- *Gastropods*—Euomphalus rugosus
- *Cephalopods.*
  - Orthoceras angulatum
  - Gomphoceras ellipticum
- *Conulariida*—Tentaculites tenius
  - Conularia monile
  - C. sowerbyi
  - C. sp.
- *Problematic*—Nidulites favus.

Shawangunk Fauna of Eastern North America.

- *Eurypterids.*
  - Dolichopterus otisius
  - D. stylonuroides
  - Eurypterus maria
  - Eusarcus cicerops
  - Hughmilleria shawangunk
  - Pterygotus globiceps
  - Stylonurus cestrotus
  - S. myops
- *No associated organisms*

Pittsford Fauna of New York.

- *Eurypterids.*
  - Eurypterus pittsfordensis
  - Hughmilleria socialis
  - H. socialis var robusta
  - Pterygotus monroensis
  - Stylonurus (Ctenopterus) multispinosus
- *Crustacea.*
  - Ceratiocaris praecedens
  - Emmelezoe decora
  - Pseudoniscus roosevelti

Fossils in dolomite partings but not in the black shales and not associated with the eurypterids.

	Genera
Graptolitida	1
Annelida (denticles)	3
Brachiopoda (Lingula)	1
Pelecypoda (Pterinea cf. emacerata)	1
Cephalopoda (Orthoceras and Gomphoceras)	2
Ostracoda (Leperditia scalaris)	1

BERTIE FAUNA.

a. Bertie fauna of Erie district.

Eurypterids.

- Dolichopterus macrochirus
- D. siluriceps
- Eurypterus lacustris
- E. lacustris var. pachychirus
- E. pustulosus
- Eusarcus scorpionis
- Pterygotus buffaloensis
- P. cobbi
- P. grandis

Associated forms.

Cephalopods—Orthoceras undulatum
Trochoceras gebhardi
Brachipod—Lingula sp.
Ostracod—Leperditia alta
Pelecypod—Goniophora sp.
Pulmonate Gastropods—Hercynella buffaloensis
H. patelliformis
Graptolites—"Buthrotrepis lesquereuxi" (formerly considered a seaweed, now identified by Ruedemann as graptolites)
Ceratiocarid—Ceratiocaris acuminata
Plant—Chondrites graminiformis (may be a graptolite)

b. Bertie fauna of Herkimer district.

Eurypterids.

- Dolichopterus macrochirus
- D. testudineus
- Eurypterus remipes
- Pterygotus macrophthalmus
- P. cobbi

Associated forms.—Scorpion

- Proscorpius osborni

KOKOMO FAUNA.

Eurypterids.

- Eurypterus (Onychopterus) kokomoensis
- E. ranilarva
- Eusarcus newlini
- Stylonurus (Drepanopterus) longicaudatus

Associated forms.

- Ceratiocarids

UPPER SILURIC FAUNA OF OESEL.

Eurypterids.

- Eurypterus fischeri
- E. fischeri var. rectangularis

E. laticeps
Pterygotus osiliensis
Eusarcus simonsoni
Ceratiocarid—Ceratiocaris
Fishes (Celphalaspid)
Thyestes verrucosus
Tremataspis schrenkii
Crustacea (Hemiaspidæ)
Bunodes lunula
B. rugosa
B. schrenkii
Synxiophosuran: Pseudoniscus aculeatus
Ostracod: Leperditia sp.
Cephalopod: Orthoceras tenue

TEMESIDE FAUNA OF ENGLAND.

While this fauna is sparingly represented in a number of beds in this group, all of the species occur together at only one horizon, namely, in the Olive shales below the Temeside Bone-Bed. Unless otherwise indicated, forms are abundant.

Eurypterids.
- Eurypterus acuminatus (r)
- E. pygmaeus
- E. spp.
- Pterygotus banksii
- P. gigas
- P. ludensis
- P. problematicus
- Parka decipiens (eggs)

Crustacea.
- Beyrichia kloedeni
- Leperditia phaseolus var. gracilenta (r)
- L. small species
- Physocaris vesica

Plantae.
- Pachytheca sphaerica (cc)

Pisces.
- Auchenaspis salteri (r)
- Cephalaspis murchisoni (r)
- Ctenacanthus (r)
- Onchus murchisoni
- O. teniustriatus

Brachiopods.
- Lingula cornea (cc)

LUDLOW FAUNA OF SCOTLAND.

Localities in Lesmahagow inlier.

(1) Along the banks of Logan water in *Ceratiocaris beds*
Eurypterid: Slimonia acuminata

Ceratiocarids.
- Ceratiocaris laxa
- Ceratiocaris longa
- Ceratiocaris papilio
- Ceratiocaris stygius
- Ceratiocaris cf. murchisoni

Worm tracks.

(2) In same bed ½ mile distant:

Eurypterids:
- Pterygotus bilobus
- Slimonia acuminata

Ceratiocarids:
- Ceratiocaris sp.
- Dictyocaris ramsayi

Coelolepid fish: Thelodus scoticus

Myriopods ? impressions of

(3) From Long Burn, tributary of Logan Water in same bed

Eurypterid: Pterygotus bilobus

Ceratiocarid:
- Dictyocaris ramsayi (Taxonomic position doubtful)
- Ceratiocaris sp.

Ostracods: Beyrichia kloedeni
- Beyrichia kloedeni var. torosa

Pelecypods: Modiolopsis nilssoni
- Orthonota sp.

Brachiopod: Lingula minima

Gastropod: Platyschisma (Trochus) helicites

Worm tubes: Spirorbis sp.

(4) One half south of Logan House in "fish-band"

Eurypterid: Slimonia acuminata

Ceratiocarids: Ceratiocaris longa
- C. murchisoni
- C. papilio
- C. stygius
- Physocaris sp.

Coelolepid fish: Thelodus scoticus
- T. planus.
- Fish fragment undet

Myriopods: Archidesmus loganensis

(5) At Logan Water in *Pterygotus* beds overlying *Ceratiocaris beds.*

Eurypterids: Eurypterus lanceolatus
- E. obesus
- E. scorpioides
- Pterygotus bilobus
- P. bilobus var. acidens
- P. bilobus var. inornatus
- P. raniceps
- Slimonia acuminata
- Stylonurus logani

Ceratiocarid: Ceratiocaris papilio
Synxiphosuran: Neolimulus falcata

Note: In same locality Pterygotus and Slimonia are found in abundance associated with *Beyrichia kloedeni* and *Ceratiocaris.*

LANARKIAN FAUNA OF SCOTLAND.

Localities in Hagshaw Hills anticline
  Glauconome layer in bed 9
  Eurypterid: Eurypterus dolichoschelus
  Coelolepid fishes: Lasanius problematicus
    Ateleaspis tessellata
  Bryozoan: Glauconome disticha
  Sponge.
  Worm tube: Spirorbis sp.

DEVONIC

OLD RED SANDSTONE FAUNA OF SCOTLAND.

a. Pterygotus beds of Carmylie.
  Eurypterids:
    Pterygotus anglicus (cc)
    Parka decipiens (eggs)
b. Acanthodian beds of Turin Hill (Arbroath flags).
  Eurypterids:
    Eurypterus brewsteri
    E. pygmaeus
    Pterygotus anglicus
    P. minor
    Stylonurus scoticus
    S. ensiformis
    S. powriei
  Fishes:
    Mesacanthus mitchelli
    Ischnacanthus gracilis
    Climatius scutiger
    C. uncinatus
    C. reticulatus
    C. macnicoli
    C. grandis
    C. gracilis
    Parexus recurvus
    P. falcatus
    Euthacanthus mitchelli
    E. elegans
    E. curtus
    Cephalaspis asper
    C. lyelli
    Thelodus pagei

Plants:
    Pachytheca, etc.
c. Old red sandstone of Lorne
  Eurypterids:
    Pterygotus cf. anglicus
  Fishes:
    Cephalaspis lornensis
    Mesacanthus
    Thelodus (?)
  Ostracods:
    Aparchites
    Isochilina
    Beyrichia
  Chilognathous myriopods:
    Kampecaris
    Archidesmus
  Plants:
    cf. Psilophyton
d. Upper old red sandstone fauna of Ireland
  Eurypterids:
    Eurypterus hibernicus
    E. scouleri?
  Fluviatile pelecypod:
    Amnigenia (Anodonta) jukesii
  Fishes:
    Coccosteus
  Plants:
    Archaeopteris
    Bothrodendron
    Calamites
    Sphenopteris
    Stigmaria
    Ulodendron

In the preceding lists only those faunas have been given which are abundantly represented in species and individuals, and which may, therefore, be considered characteristic. Of all the faunas cited, that from the waterlimes of Oesel, while not containing the largest number of species, is yet the one which is preëminently representative. The eurypterids undoubtedly lived and died in the muds now forming the waterlimes, the remains which are found there having suffered practically no transportation, as we may judge from the perfection of preservation and the entirety of individuals. The specimens of *Eurypterus fischeri* occur in greater numbers and in a more perfect state than do those of any other known species, and the exoskeletons are not only not compressed, but they even show the original chitin and specimens can be removed from the rock almost entire; the surface sculpture and internal structure are as clearly visible as in a Limulus buried in the sand but yesterday. We have here, if anywhere, a representation of the normal habitat of the Eurypterida, and likewise the normal faunal associates. The analysis of this fauna shows that besides the eurypterids there are a number of crustacea which are commonly found with the merostomes, but never in a typical marine fauna, two species of fish of the type characteristic of the Old Red Sandstone, an ostracod and *Orthoceras tenue*. The presence of this single cephalopod has been considered by some authors to be so important that they would brand the whole fauna as a modified marine one, because of it; and yet the startling and commonly neglected fact is that this thin shelled Orthoceras is most evidently out of place, for while the eurypterids are so marvellously preserved, this one rare cephalopod is worn, macerated, and flattened into a tenuous, carbonaceous film, and thus there is no doubt that it was transported from its normal habitat and came probably as a dead shell into the region where the eurypterids were living. Its presence is truly of great importance as being the very exception which proves the rule that the eurypterids were not normally marine.

A glance at the components of the fourteen faunas listed shows that there is not a single case in which several species of eurypterids are found in a fair state of preservation in such numbers as to be considered a recognizable faunule—there is not a case, to repeat, in which the faunule, including all of the organisms represented, can be considered either marine or modified marine, that is, brackish or estuarine. The most constant associates of the eurypterids from the earliest Siluric on are certain peculiar crustaceans, Ceratiocaris, and the like, which are never found with the molluscs, brachiopods, and trilobites which are characteristic of marine faunas. The oldest scorpion known comes from beds carrying eurypterids, similarly the earliest fluviatile pelecypod and the first myriopods were also found in eurypterid formations. In North America, England, Scotland, and on the continent the forerunners of the Old Red Sandstone fishes, now almost universally recognized to be fluviatile, are found in the Siluric with the eurypterids, crustacea and spores of land plants, but not in the beds carrying typical marine fossils.

In the Bertie waterlime, which is second only to the waterlime of Oesel in importance, a large eurypterid fauna is found with abundant Ceratiocaris, two species of pulmonate gastropods, a problematic plant, and a few very poorly-preserved, marine fossils, which last, by their very scarcity and by the evidences which they show of having been transported, argue more strongly for than against the extra-marine habitat of the well-preserved eurypterids and Ceratiocaris.

The application of the criteria for the recognition of the types of fossil faunas and habitats shows beyond any doubt that the eurypterids, so far as we now know, never lived in the sea or in any partially or wholly detached portion thereof; the only possible type of fauna to which the eurypterids could have belonged was that which dwelt in rivers, and this is nowhere more clearly shown than in the Siluric, which marked the acme in development and universality of distribution for the Eurypterida.

CHAPTER IV

The Lithogenesis of the Eurypterid-bearing Beds

The formations which in America contain eurypterids in abundance are:

1. The Belt Terrane.
2. The Normanskill and Schenectady beds.
3. The Shawangunk conglomerate.
4. The Pittsford shale.
5. The Bertie waterlime.
6. The Kokomo waterlimes.

Those most prolific in Europe are:

7. The Tarannon and Wenlock beds of southern Scotland.
8. The waterlime beds of Oesel.
9. The Siluric of the Austro-Russian border lands.
10. The Ludlow of England and Ludlow and Lanarkian of Scotland.
11. The Old Red Sandstone.

It is evident that the formations carrying only fragments or single individuals need not be considered if we can prove a uniform habitat from the formations carrying these merostomes in abundance. Nevertheless a brief summary of these is also given at the end of the chapter.

1. THE BELT TERRANE

The Belt Terrane fauna is a large one made up of fragments which Clarke and Ruedemann have failed to identify as of merostome origin, though Walcott insists that they belong to this group. Clarke and Ruedemann hold, however, that the specimens from the Altyn limestone of Alberta are undoubtedly merostomes, but they question the correlation of the Altyn and Belt Terrane, and the consequent reference of the remains from the two formations to *Beltina danai*. (This has been discussed on pp. 11-13.) The Belt Terrane material, nevertheless, has a very strong resemblance to the eurypterid fragments from other horizons, though the specimens all lack the surface markings characteristic of the eurypterids. Some of the most typical material is figured on plate 25 in the *Bulletin of the Geological Society of America*, Vol. X, 1898, and again in the *Smithsonian Miscellaneous Collections*, Vol. LXIV, No. 2, plate 22.

Of the conditions of sedimentation prevailing during this period Walcott says:

"Briefly summarized, the Algonkian period in North America with its great epicontinental formations was a time of continental elevation and largely terrigenous sedimentation *in non-marine bodies of water*, and of deposition by aerial and stream processes in favorable areas. . . . .

"The North American continent was larger at the close of Algonkian time than at any subsequent period other than possibly at the end of the Cretaceous, when the land was equally extensive. Indeed. it is highly probable that its area was greater then than even now, for no marine deposits of Algonkian age containing pre-Cambrian life, as they were laid down in Lipalian[1] time immediately preceding the Cambrian period have been discovered on the North American continent or elsewhere, so far as known" (**290**, 81, 82).

Walcott does not wholly subscribe to the fresh water habitat of these eurypterids early for he speaks of *Beltina danai* as "possibly of marine derivation" and uses the presence of this fossil in the Belt Terrane as an indication that a connection of the Cordilleran geosyncline with the sea was temporarily effected allowing "at least a crustacean, and a few annelids" to become adapted to the Montana-Alberta sea. It is clear that Walcott allows this entrance of the sea into the Beltian lake only in order to account for the presence of the eurypterids and annelids and to conform to the prevailing opinion that the early eurypterids were marine organisms. This concession seems to be unnecessary. The annelids surely would be more naturally accounted for as terrestrial forms and besides, it would scarcely be possible for them to leave their trails in deposits formed under water. Such trails would have to be made on surfaces exposed to the air long enough to harden and to be covered by wind-blown sand or dust or by a fresh deposit of water-laid material, but in the latter case a sufficient length of time would have to elapse to allow of the thorough hardening of the trail. In this case as in many another the question must be raised: Why if the eurypterids were marine were they the only organisms which were carried in from the open sea? It is well known that the littoral waters of the Pre-Cambric must have teamed with all the forms of life which are so abundantly represented in the advancing Cambric waters. It seems absurd to suppose that thousands of fragments of a eurypterid should have been washed in from the sea, but no other marine form.

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[1] Lipalian is a term proposed by Walcott in 1899 "for the era of unknown marine sedimentation between the adjustment of pelagic life to littoral conditions and the appearance of the Lower Cambrian fauna. It represents the period between the formation of the Algonkian continents and the earliest encroachment of the Lower Cambrian sea" (**290**, 82).

The great thicknesses of Algonkian limestone found in the Belt terrane and corresponding formations have been adequately accounted for by Walcott as algal deposits in a series of lakes formed within the Cordilleran geosyncline. "The lakes of Algonkian [Pre-Cambric[2]] time were not much if any larger in area than the 'Great Lakes' of the St. Lawrence drainage basin and they were much shallower and more laden with mud and mineral matter in solution.

"The area of the Belt terrane in Montana is about 6000 square miles. This seems large when studying it in the field, but it is only one-fifth of the size of our great fresh-water Lake Superior" (**290**, 89).

Walcott has described nine species of calcareous algae from the Newland limestone below the Greyson shales and one which is abundant in the Spokane shales just above the Greyson. It is much more logical to suppose that the Greyson shales represent river rather than marine deposits, for they are coarse and arenaceous with interbedded shales, in which algal reefs could not grow. This would account for the absence of the reefs in the Greyson and for the absence of the eurypterids in the Newland limestone. I make this suggestion merely as a more plausible explanation of the conditions than the one which is usually offered.

If it can be assumed as proved that the remains in the Belt Terrane are of eurypterid affinity, they would offer just the proof desired to show that the eurypterids from the earliest times lived in terrestrial waters, for the Belt terrane has been shown by Barrell from purely lithological evidence to be non-marine. From the presence of mud-cracks and other structural characters of the formation he concludes that the terrane gives evidence of "two sedimentary cycles, each of which contains a strongly marked formation of mud-cracked red shales, the shales alternating with sandy strata, and both judged to have been deposited on the flood plains of rivers, whose deltas had gained over the subsidence, finally filling up and displacing the shallow epicontinental sea" (**14,** 319, 320).

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[2] The Belt terrane is considered by Professor Grabau as representing a pre-Cambric Palaezoic terrestrial deposit lying above the true Algonkian.

2. THE NORMANSKILL AND SCHENECTADY BEDS

The Normanskill sandstones and shales of Catskill and the Schenectady bluestones of Schenectady, New York, are so similar lithologically and faunally that they may be considered together. Comparatively little is known concerning the details of distribution of these formations and their physical changes from place to place, yet the descriptions available and the studies I have been able to make in the field, make clear what must be the origin of the sediments. In reference to the Normanskill beds Clarke and Ruedemann make the following statement:

"The lithologic and faunal conditions at the Broom street quarry exposure were found to be a singularly complete duplication of those of the eurypterid-bearing exposures in the bluestone quarries at Schenectady. The Broom street quarry is also a bluestone quarry, the rock being mostly used in the crusher. The courses of 'bluestone' (here an impure argillaceous sandstone) are very compact, from 3 to 30 feet thick between the intercalations of black shales. There is distinct evidence of shallow water conditions, one bed being conglomeratic and largely composed of pebbles, many of which appear to be mud pebbles; another beautifully exhibiting very regular, widely separated wave marks with winnows of comminuted seaweeds and eurypterids in the troughs.

"Quite as in the bluestone quarries of the Schenectady beds, the surfaces of some of the sandstones are densely covered with rather poorly preserved seaweeds and eurypterids. It was therefore natural to expect that here too the black intercalated shales would contain better material of these fossils and possibly also graptolites that would indicate the age of the beds. They have indeed afforded a layer with an association of finely preserved seaweeds, the eurypterids herewith described, and the following graptolites: *Dicellograptus gurleyi* Lapworth, *Climacograptus bicornis* Hall, *Climacograptus bicornis* var. *peltifer* Lapworth, *Cryptograptus tricornis* (Carruthers), the first three forms in great abundance. This graptolite association is one of undoubted Normanskill age. The seaweeds occur in large perfect fronds and are of the same type as those in the Schenectady shale. The eurypterids also are strikingly similar to those from the Schenectady beds" (**39**, 411, 412).

The eurypterid remains are very fragmentary, in fact, they are so incomplete that generic determinations are only provisional, there being but a few carapaces and fragmentary abdomina with a small number of legs and telsons rarely attached. Five genera are thought to be represented: Eurypterus, Eusarcus, Dolichopterus, Stylonurus by one species each, and Pterygotus by two species, though one of these may be a Eusarcus.

The physical characteristics of the Schenectady beds are closely similar to those of the Normanskill beds. Both consist of heavy bedded sandstones, dark in color, but highly siliceous, alternating with black shales. The sandstones are compact enough to be quarried for building and paving purposes. Both the shales, and bluestones change westward into shales, and eastward become very coarse. In the Normanskill beds pebble layers alternate with the sandstones, while in both formations mud cracks are found in the shales and subsolifluction contortions in the sandstones, structures which show a slumping motion of the sands along the shore (Berckhemer, **21**). The sandstones contain eurypterid and plant remains, the latter identified as *Sphenophycus latifolius*, and having a remarkably thick carbonaceous test which is so high in carbon that it will burn. In the shales occur the graptolites and eurypterids, the latter not being so abundant as in the sandstones, but exhibiting better preservation.

The sediments of both the Normanskill and the Schenectady were undoubtedly derived from the east as the following facts indicate: (1) Coarse materials, conglomerates and sandstones with intercalated shales in east along Schenectady-Catskill line, passing laterally into fine black shales westward in the Mohawk Valley; (2) deposits thicker and coarser in east than in west; (3) evidences of shore conditions in sun-cracks, wave marks, and subsolifluction, in east, of conditions in quieter water farther from shore in the fine black shales westward. Appalachia was the only large land area to the east from which siliceous sediments could come, and the characteristics of the sediments just noted clearly point to that continent as the source.

It will probably be readily accepted that the Normanskill and Schenectady are of terrigenous origin, especially since they are several thousand feet thick, but the point which is difficult of determination, is the origin of the fauna of these formations. That the sediments were fluviatile does not at all imply that the organisms in those sediments were also fluviatile. Indeed, it is usually argued that the presence of graptolites and "sea-weeds" in the same beds with the eurypterids is ample proof that all these types of life were marine and that they lived in the littoral zone in the sandy and muddy facies. First, in regard to the "sea-weed" *Sphenophycus latifolius*, there is no reason that I know of why such plant remains could not have been washed in from the land or might not have been living in the rivers, and have thus been swept into the sea. Secondly, it is evident that the presence of graptolites does not indicate deep sea conditions of quiet sedimentation as so often stated. Certainly, there is nothing incompatible with the assumption that the graptolites were spread out on mud flats, or river flood-plains as modern hydroids are, when washed in by the sea. At least the possibility must be granted that the pelagic graptolites would after death be more likely to float near or on the surface of the water until thoroughly decayed and disintegrated, rather than sink to the bottom, and be buried by sediments. In such a case, their only chance for preservation would be through stranding upon some surface where they could be quickly entombed by layers of mud or sand. This line of argument has only just been propounded by Professor Grabau, and while heretical it yet explains many curious occurrences.[3] Thus, although no definite statement can be made at present regarding the precise habitat of the graptolites, we may consider that it is reasonable to assume that their remains are chiefly found in formations accumulating near land especially on delta surfaces. If the graptolite-bearing beds are thin we may suppose that they were formed by frequent inundations from the sea, but when 1500 feet thick, as is the case of the Schenectady beds throughout the entire thickness of which graptolites occur at intervals, then the only interpretation is that the beds were a series of flood-plain and delta deposits, mostly above sea-level, and that the graptolites were stranded on the low-lying land areas by periodic incursions

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[3] Professor Grabau has discussed this subject very fully in his lectures, with especial reference to the Graptolite beds of Europe. He expects to publish soon on this subject.

of the sea. It is often argued that such alternations of sandstones and shales as we see in this series indicate near-shore oscillatory conditions, the shales marking a slight advance of the sea and of fine deposition, the sands marking a retreat and the seaward advance of continental clastics. In the present instance it is difficult to explain the presence of eurypterids as marine organisms if we account for the lithological variation in the customary manner, for it is in the *sandstones* which mark the dominance of terrigenous sedimentation that the eurypterids are more abundant, while they are scarce in the shales which accompany the advance of the sea. If they were living along shore they should be abundant in the shales. The reply may be made that the eurypterids at that time preferred the sandy facies only and that the occurrence of dead individuals or shed exoskeletons in the muds was fortuitous. A phenomenon can hardly be called fortuitous which occurs again and again in response to a given set of conditions. Furthermore, if the eurypterids did live in the sandy facies then there is no reason why their remains should not have been preserved, for it is a mistake to believe that such exoskeletons would be destroyed by the waves, except perhaps on a shingly beach, a facies with which we are not here concerned. A short distance out to sea eurypterid remains would quickly be buried, the hollow case being soon filled by infiltrating sand. Anyone familiar with the occurrence of Limulus exoskeletons on sandy shores knows that they are easily filled by and buried in the sand and that they are preserved in toto, not broken to pieces. Thus we cannot account for the occurrences of the eurypterids on the assumption that they are marine organisms. In the Normanskill beds not a single entire specimen has been found, the whole fauna being made up mostly of carapaces with some separated abdominal segments. In the Schenectady sandstones the conditions are the same, but in the shales the preservation is better.

The evidence clearly militates against a marine habitat for the eurypterids in these two regions and the hypothesis of a fluviatile origin while not yet very strongly supported at least accounts for the observed facts. If the eurypterids were living in the rivers in Middle and Upper Ordovicic time, then it is to be expected that their remains would be carried out to sea. In rivers of moderate gradient it is not so likely that an abundance of remains of fluviatile organisms will be washed seaward, for they may be entirely broken up during transportation, or they may be caught in hollows along the banks, or even buried; but in eastern New York during the later stages of the Ordovicic the streams did not have a moderate gradient. The elevation of the land leading up to the tectonic movement known as the Taconic folding which displaced the rocks in some regions in the Hudson Valley as much as 90° was in progress at least throughout the Upper Ordovicic. One of the results of this movement was the steepening of the gradients of the streams which thus became torrential, not necessarily through increased rainfall, but through increased gradient. The streams consequently brought great quantities of clastic material to the margin of, and into the sea, where deposition probably went on in a sinking geosyncline.

SUMMARY. The physical characters of the Normanskill and Schenectady beds point to Appalachia as the source of the sediments. The mode of occurrence of the eurypterids, graptolites and plant remains is better explained on the hypothesis that the eurypterids and perhaps the plants also were fluviatile and not marine organisms. As yet the Ordovicic merostome faunas are too little known to say that the habitat can be proved to be one or the other; the most that we can say is that all the known facts are better accounted for by the fluviatile hypothesis, which is fully supported by the palaeontological and chorological data.

3. THE SHAWANGUNK CONGLOMERATE[4]

In the intercalated shales in the Shawangunk conglomerate at Otisville, Orange County, New York, and at the Delaware Water Gap and elsewhere a large eurypterid fauna has been discovered. The Shawangunk is distributed in the form of a semi-cone, having its greatest thickness, about 2000 feet, in the Delaware Water Gap region, and thinning away in all directions. That is, it has the form of a dry delta or alluvial fan rather than of a sea coast deposit, for if it were the latter, it would be of fairly uniform thickness and would not have the semi-cone shape. The pebbles in the conglomeratic portion of the Shawangunk are well rounded, but in some sections a certain amount of angularity is still retained as a rule. For river-worn pebbles to be perfectly rounded, they must be transported for a considerable distance. Again the complete destruction of all but the quartz argues for prolonged transportation and frequent reworking. As in the case of the other clastics, there was no source for the conglomerate to the north, south or west, the only possible one being to the southeast where lay the old land of Appalachia. This is also indicated with great certainty by the shape of the cone of this formation which is thickest in the southeast, thinning out to the north, west and south. The material of this alluvial cone could only have been transported by rivers and its river-borne character and deposition upon land are well shown in the frequent occurrence of the torrential type of cross-bedding, and in the absence of any typical marine organisms, such as would be found in the subaqueous portion of a delta. Apparently there was no sea-border portion of this deposit, unless the Pittsford shale is considered as such. The Shawangunk conglomerates found in Pennsylvania and New York, thin away towards the region of Pittsford shale deposition, but actual connection has not been traced. There can, however, be little doubt that the Pittsford shale represents the finest material brought by the Shawangunk river from Appalachia. This mud was deposited very near the sea border, but there is no evidence that it was deposited in the sea, since the typical marine organisms are absent. It may be that the influx of fresh water was sufficient to keep these out. Interfingering with the shale, are the dolomite beds, deposited during short incursions of the sea (see section 4). If we could trace these Pittsford shales to the northern part of the state or into Canada, we would expect to find them grading into pure marine limestones, but no outcrops are accessible. The black shales intercalated between the conglomerate beds of the Shawangunk at Otisville and elsewhere represent the muds carried down by the river during times of flood. If the eurypterids were living in those rivers, their exoskeletons would have been floated down, while dead and even living individuals would have been swept down by the force of the torrential floods. The exoskeletons and floating bodies would settle down with the mud on the drying up of the water from the flooded areas. That such drying occurred is indicated by the presence of mud-cracks in these intercalated shales. When this mud dried up and became cracked, the eurypterid exoskeletons would be broken up and blown about by the wind, until the fragments should be covered by the next torrential deposit. This breaking up of the tests as the mud dried would account for the fact that the larger eurypterids are always found in a fragmentary condition, while the smaller ones are found whole. How to account for this fact on any other hypothesis is difficult to see.

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[4] The lithogenesis of this formation has been discussed in such detail by Grabau (Early Palæozoic delta deposits) that it is unnecessary to give more than a summary here.

4. THE PITTSFORD SHALE

This formation is typically developed in the western part of central New York where, in the town of Pittsford, Monroe county, the following section is shown (Sarle, **240,** 1082):

	FEET	INCHES
1. Red shale	6	
2. Light gray, compact, fine-grained, dolomite, with imperfect conchoidal fracture, weathering light brown to cream color		10
3. Soft, gritty mud-rock, purple with bright red mottlings	1	3
4. Dolomite like No. 2		4
5. Purple shale with red mottlings	1	11
6. Green shale	1	2
7. Thin layer dolomite like No. 2		4
8. Black shale, very compact, the base splitting unevenly; grading to olive-green shale in the upper part		10
9. Dolomite like no. 2		10
10. Black shale, with leaf of dolomite ½ inch thick four inches from its base	1	2
11. Dolomite like no. 2		2
12. Soft, green, arenaceous mud-rock, occasionally becoming shaly; the lowest exposed rock of the cut	1	8

The eurypterid fauna occurs in the black shales, Nos. 8 and 10.

A more complete section is shown in the wells of the region, from which the exact location of the fossiliferous black shale beds is ascertainable. The section carries the series down to the Lockport-Guelph horizon.

Salinan

	FEET	INCHES
1. Red shale or marlite	10	
2. Hard, fine grained, yellowish, dolomite, having an imperfect conchoidal fracture	2	
3. Red shale	1	
4. Break estimated at	3	
5. Dolomite like No. 2	3	
6. Green shale or marlite	4	
7. Red shale	1	8
8. Break estimated at about	2	
9. Green shale	2	5

Salinan—Continued

	FEET	INCHES
10. Black shale, very fine textured, fissile, and with 1 inch dolomite parting (eurypterid horizon)	1	6
11. Green shale	1	
12. Dolomite like No. 2	2	
13. Green shale or marlite	6	
From West Branch of Allen Creek		
14. Light colored waterlime, some pyrites and sun cracks	5	
15. Pea-green shaly marlite	7	
	51	7
Niagaran		
16. An impure yellowish porous limestone		
17. Succeeded by an impure bituminous limestone made up of imbricating, shell-like domes, etc		

It is thus seen that there are 41 feet 7 inches between the Lockport dolomites and the Vernon red shales, although there are two initial red beds, Nos. 7 and 3, showing that the red shale sedimentation was already in progress. A comparison of the two sections shows that the first bed of red shale (No. 7) comes at from 2 to 5 feet above the upper eurypterid-bearing bed, while the lower eurypterid bed (No. 10) occurs 21 feet above the typical Lockport-Guelph. In the lower interval are several thin beds of dolomite, and a waterlime showing sun-cracks occurs. The two shale beds are separated by a dolomite bed 10 inches thick, and in the lower black shale is a dolomite parting ½ to 1 inch thick. The thin dolomite beds are often sun-cracked, indicating temporary exposure during formation.

The formations indicate a progressive change of conditions from those of Niagaran (Guelph) time when the widespread Stromatopora reefs were forming and the Guelph fauna flourished, through the period when impure dolomites were deposited in thin, ripple-marked layers containing some marine organisms and "fucoids," followed by conditions favorable to the formation of the impure bituminous limestone, to the final stage of the deposition of the impure porous limestone, 2 feet in thickness and containing a branching organism thought by

Sarle to be a plant. Upon this bed lies the shaly marlite, the first of the lowest Salina or last of Upper Niagaran,[5] and above this a waterlime.

There is thus a marked change in the physical conditions which accompanied the withdrawal of the Niagaran sea and the initiation of the Salina type of deposits. In the lowest bed of the series occurs the last of the Niagaran fauna, *Pterinea cf. emacerata*. In the waterlime (no. 14) the same species occurs, together with a Lingula, *Leperditia cf. scalaris* and an Orthoceras. Then not again till the black shale of the eurypterid horizon, do these forms appear, but it is of great significance that these pure marine fossils do not occur in the eurypterid shale beds proper, but in the thin dolomite partings, and that in these partings the eurypterids are almost entirely wanting. The dolomites were evidently marine, but the conditions under which they were deposited "were not favorable to the eurypterids" says Sarle (**240**, 1086). The question immediately arises: why were the conditions not favorable? and then, where were the eurpterids during the intervals between shale deposition, i.e., during the time of marine dolomite deposition? If the eurypterids were inhabitants of the marine waters or of bays, estuaries, etc., they should be found in the beds containing the littoral fauna of the impure dolomite, for, as has been shown in Chapter III, the faunas of bays and other indentations along the shore are not restricted to such areas, but are much the same as the faunas extending all along a continental shore line. Since the eurypterids were not living in the marine waters, where were they when there were no black muds forming? They appear suddenly in countless numbers representing six species, and they come with the black shale facies and disappear again just as suddenly. Their range, too, is very small. Sarle says: "Though the fine character of the silt forming the black shale and the evidence of interrupted sedimentation noted above, indicate slow accumulation, the occupation by the eurypterids was apparently of comparatively short duration, merely an incursion, as it were, since the black shale all told does not exceed 2 feet in thickness" (**240**, 1086).

To determine where the eurypterids were before their two sudden appearances, one must turn to the source of the black muds. These were not deposited in the open sea, for marine forms are wanting, and in any case, the mud must have been derived from the land. At that time the land to the west, north and south was all covered by the Niagaran limestones which would furnish pure clastic limestones and not impure siliceous muds. The only area from which the muds could be derived, was the land to the east. That the black mud was merely an extension of the muds forming at intervals on the Shawangunk delta must be obvious when it is seen that in that direction was the only source of the muds and that the Shawangunk muds contain the same eurypterid fauna. This will be more fully discussed in Chapter V.

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[5] Professor Grabau has recently voiced the opinion, that the Pittsford shales and Shawangunk conglomerate are better considered as the closing deposits of the Guelph period.

The areal distribution of the Pittsford is limited. The shale is known from Monroe county and from Oneida county, New York. Both eastward and westward it dies out, the Vernon red shale resting directly upon the Niagaran. In a few localities black shales have been found which have been correlated with the Pittsford, but they contain no eurypterids. Such is the black shale at Buffalo, on Grand Island, and the dark shale in Herkimer county above the Lockport dolomite which contains no fauna except a few Lingulas. The outcrop in Oneida county is at Oriskany creek, where in a bluff occur some dark gray shales, about 21 feet below the base of the Vernon red shale, with intercalated waterlimes and dolomite beds. These dolomites contain fragments of one species, *Eusarcus vaningeni*, together with lingulas and orbiculoideas. Both the areal and vertical distribution, then, are limited, in much the same way as in the Bertie, and the source of this calcareous material may likewise be the same. (See beyond, p. 234.)

If the eurypterids of the Pittsford shale were brought in by the rivers coming from Appalachia, the waters in the region of deposition would become freshened by the inpouring of the river waters, and marine forms would thus be kept out. It is often assumed that the Pittsford shale marks a periodic increase in the salinity of the water, but in that case we are faced by a double problem: if the muds were not deposited by rivers, where did they come from, since they could not have originated in the sea? and then again, the question arises, where did the eurypterids suddenly come from? The muds might be æolian, but not the eurypterids. The only possible conclusion seems to be that the eurypterids and the black muds both were brought by rivers from the land, i.e., that the eurypterids were river-living organisms.

In this connection attention may be called to the fact that the species of eurypterids in the Pittsford and Shawangunk and to some extent the genera as well, are entirely different from those of the Bertie. This is not alone accounted for by difference in age, but is more especially due to difference in origin. The sediment of the Bertie and its fossils came from the continent of Atlantica, and those of the Pittsford from Appalachia. This is more fully discussed in a subsequent chapter (see p. 229).

5. THE BERTIE WATERLIME

The Bertie waterlime of Upper Siluric or Monroan age is confined to central and western New York, and the adjacent portion of Ontario, Canada. It is a gray, fine-grained, argillaceous calcilutyte of a remarkably uniform character, showing practically no variation in texture from place to place. Chemical analysis has shown it to be an impure limestone, high in magnesia, silica and alumina. The following analysis is that of an average specimen (**39,** 101).

$\mathrm{Si\ O_2}$	11.48
$\mathrm{Al_2O_3}$	17.50
Iron	0.90
$\mathrm{CaCO_3}$	42.75
$\mathrm{MgCO_3}$	20.35
$\mathrm{K_2O}$	1.00
$\mathrm{Na\ Cl}$	0.80
Combined water and loss	5.22

A typical section of the Bertie is exposed at Buffalo where Pohlman has recorded the following succession the lower part being obtained from borings. (See also Grabau, **82,** 115).

Akron dolomite

		Feet
Bertie	Waterlime, about	7
	Shale and cement rock in thin streaks	25
	Tolerably pure cement rock	5
	Shale and cement rock in thin streaks	13
Camillus	Pure white gypsum	4
	Shale	2
	White gypsum	12
	Shale	1
	White gypsum	4
	Shale and gypsum, mottled	7
	Drab colored shale with several thin layers of white gypsum	58
	Dark colored limestone	2
	Shale and limestone	4
	Compact shale	3
	Gypsum and shale, mottled and in streaks, approximately	290 plus

Here we see that the Bertie follows upon the Camillus shales and gypsum, a part of which may belong to the undoubted Salina or Middle Siluric, but the upper part of which certainly belongs with the Bertie to the Upper Monroe, since it contains *Leperditia scalaris.* At Buffalo the Bertie is conformably succeeded by the Akron dolomite, an impure rock 7 or 8 feet thick, containing the Upper Monroe fauna sparingly distributed, and marking the return of normal marine conditions.

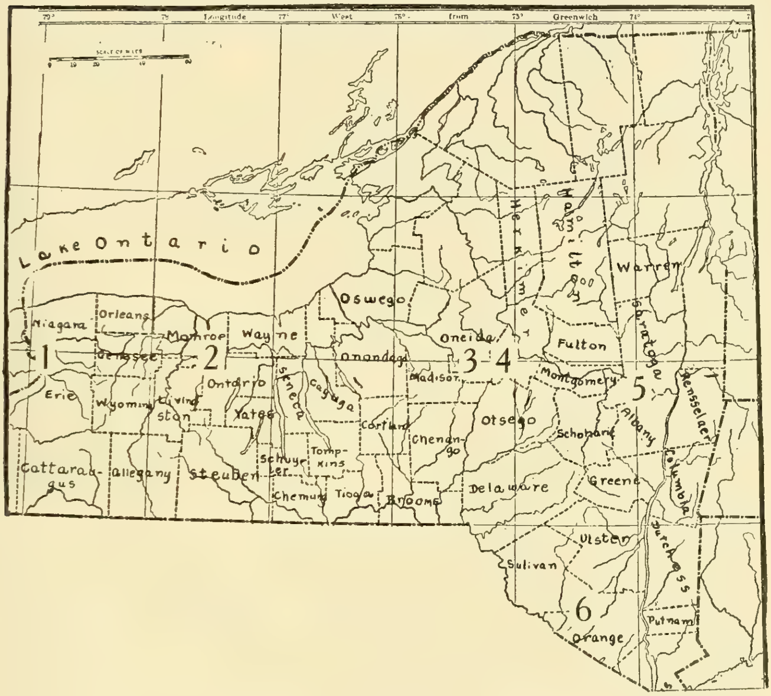
79°
78°
Longitude
77°
West
76°
from
75°
Greenwich
74°
Scale of miles
0
10
20
40
60
Lake Ontario
Niagara
Orleans
Monroe
Genesee
Wayne
Oswego
Oneida
Fulton
Warren
Saratoga
Rensselaer
Erie
Wyoming
Living ston
Ontario
Yates
Seneca
Cayuga
Onondaga
Madison
Cortland
Chenango
Otsego
Montgomery
Schoharie
Albany
Columbia
Greene
Delaware
Ulster
Sullivan
Orange
Putnam
Dutchess
Cattaraugus
Allegany
Steuben
Schuyler
Tompkins
Chemung
Tioga
Broome
1
2
3
4
5
6

FIG. 2. SKETCH MAP OF NEW YORK SHOWING LOCATION OF IMPORTANT EURYPTERID-BEARING BEDS

1, Buffalo and Williamsville; 2, Pittsford; 3, Waterville; 4, Litchfield and Cranes Corners; 5, Schenectady; 6, Otisville.

In areal distribution the typical Bertie is not a continuous formation, but is found well developed at only two localities; namely, in Erie and in Herkimer Counties, New York, where the sediments were deposited in what Clarke and Ruedemann have called the Buffalo and Herkimer "pools." These two pools or basins are considered to have been of circumscribed area; the Buffalo pool extending from Bertie, Ontario, eastward into Erie County; the Herkimer pool being confined most of the time to the southern part of Herkimer County (See map, fig. 2). In spite of the faunules as a whole having such a restricted distribution, the *Eurypterus lacustris* of the Buffalo region has been found as far east as Union Springs, Cayuga County, although not at intermediate points, and *E. remipes,* the characteristic form of Herkimer County, has been found to the west at Waterville, town of Westmoreland, Oneida County, and still farther to the west in large numbers at Oriskany, Oneida County, at Cayuga Junction, Cayuga County, and possibly even at Buffalo. *Dolichopterus macrochirus* and *Pterygotus cobbi* are common to the two "pools."

THEORIES OF ORIGIN. A careful determination and a thorough understanding of the conditions under which the Bertie waterlime was deposited are essential in the attempt to determine the habitat of the organisms found in that rock. Because no one has yet given an exhaustive treatment of all possible conditions of deposition with a final singling out of the true one; and because, moreover, the answer to this question of deposition furnishes one of the most important lines of evidence concerning the habitat of the Eurypterida, I shall take up a detailed discussion of the subject. Such a fine-grained, stratified rock might have been deposited in one of the following four ways, and these appear to cover all possibilities: (a) by chemical precipitation; (b) by bacterial precipitation; (c) by the formation of an organic accumulation of calcareous shells or plants, or both; (d) by the accumulation of clastic or fragmental material.

(a) *Chemical origin:* That the Bertie waterlime could not have been deposited by chemical precipitation is amply shown by its stratification and especially by its composition. A rock which is a chemical precipitate, is more likely to be massive, never showing such fine stratification as is found in the Bertie, for in the process of chemical precipitation there is no arrangement of the material by currents bringing in fresh supplies which vary slightly in color or texture and which when deposited make the separate layers which produce stratification, since in precipitation the action is more or less continuous and minute crystals are formed which either entirely make up a rock, or else cement into a compact mass, fine particles of clastic material as is the case around modern coral reefs. The texture of a chemical precipitate would be a finely crystalline one, whereas the material of the Bertie does not conform to this, for a thin section of the water lime shows under the microscope an exceedingly fine-grained lime mud, the grains being angular and of varying sizes, with rhombic crystals of dolomite scattered through the mass of calcite fragments. There are also many fine, black specks, probably of carbonaceous material. The most significant fact of the composition, however, is the presence of the silica and the alumina, which forms nearly one-third of the rock. Such a composition is entirely incompatible with the idea of chemical deposition, where we should expect practically pure carbonates.

(b and c) *Organic origin.* If the Bertie were an organic deposit its fine texture would permit of only two types of organisms active in its formation, namely, the protozoa or the algae. The lime content might be supplied by Foraminifera or by lime-secreting algæ, the silica by Radiolaria. The microslide of the Bertie shows no trace of any of these organisms. One other method of organic deposition is possible. The work of Drew, Sanford, and Vaughan has recently shown that in warm or tropical seas certain bacteria are active in precipitating calcareous muds from the sea water. That the Bertie waterlime could not have had such an origin is evident from its chemical composition given on page 106 above, in which the silica and alumina play too important a part, amounting to 28.98 per cent of the whole.

Since the chemical and microscopic study of the Bertie proves the impossibility of either a chemical or an organic origin, we must conclude that the rock is clastic.

(d) *Clastic origin.* A rock of clastic origin may have one of two sources: (1′) it may be composed of material which was originally derived from the sea, that is, it may be thalassigenous, or (2′) it may be derived from the erosion or breaking up of a pre-existing rock on the land, that is, it may be of terrigenous origin.

(1′) Organic material broken up in the sea by organisms, or along the shore by waves, consists of shells, corals, and other hard parts of organisms mixed with varying amounts of sands and muds, organic and inorganic, the composition depending on the character of the rock supplying the detritus. Such clastic deposits are especially well developed around coral reefs where the purely biogenic rocks grade laterally in all directions into the clastic ones. That the Bertie waterlime could not have been a lime mud derived from the erosion of coral or other reefs and deposited in the surrounding quieter water or in the lagoons, as in the case of the similar, fine-grained lime mud forming the Jurassic Plattenkalke of Solnhofen, is shown by the utter absence in this horizon or vicinity of reefs which could furnish such deposits, and again by the presence in the composition of the silica and alumina. In the Bertie the silica and the alumina is intimately mixed with the lime, as is shown by the relative constancy in composition and character of specimens from different parts of the formation. In the Plattenkalke of the Solnhofen, on the other hand, where the siliceous material represents the impure dust blown from the land, it is found in clayey layers (*Fäulen*) between the thin bedded (*Quicksteine*) and thick bedded (*Flinze*) limestones, and not in intimate mixture with the other constituents, as is the case in the Bertie (**293**, 144, 209).

(2′) The only remaining source of the deposit is the land, from which clastic material might be brought by the wind or by the rivers. If brought by the wind and deposited far enough from shore to be free from coarse material, the deposit would not have a circumscribed areal distribution. Such a restricted distribution is, however, possible if the material has been supplied by the rivers. If carried into the sea, it may be deposited in quiet water, and this may produce such a fine-grained rock as the waterlime, which is free from coarse clastics. Such regions of deposition would be found either far out at sea where all of the nearer-shore, coarser clastics were absent, or else near the shore, but in sheltered bays. If these river-borne muds were not carried into the sea, then they must have been deposited on land in the river flood-plains.

We may consider for a moment the possibility of this formation having been deposited at a sufficient distance from land to allow of the quiet accumulation of fine sediments, or else in sheltered areas along shore. Such deposits at the present time are represented by the blue or slate-colored muds, and these are the ones which are spread over the floors of shallow seas and out to the edge of the continental shelf. Murray and Renard (**194**) have estimated that these muds cover 14,500,000 square miles of the ocean floor. An average analysis shows the following composition:

Ignition	5.60	$CaCO_3$	2.94
SiO_2	64.20	$Ca_3P_2O_8$	1.39
Al_2O_3	13.55	$CaSO_4$	0.42
Fe_2O_3	8.38	$MgCO_3$	0.76
CaO	2.51		
MgO	0.25		100.00

A comparison of this analysis with that of the Bertie shows that the two types of deposits are as different as could well be imagined, the deep sea mud having combined alumina and silica 77.75 per cent, as opposed to 28.98 per cent, while the combined CaO and MgO is 5.00 per cent as compared to 63.10 per cent in the waterlime. One cannot argue much, however, from this pronounced difference between the two types, because it must be borne in mind that in the late Siluric the greater portion of exposed land areas in northern and western North America was covered with limestones or dolomites and that in consequence the muds which accumulated far out to sea, and which were the finest particles derived by the erosion of those land surfaces, would of necessity have been high in calcium and magnesium, whereas the blue muds accumulating in our present oceans are derived from a great diversity of rocks in which the limestones form a very small part. Thus, while we can find no analogous mud deposit in modern oceans, we are not justified in saying that such a one might not have formed in the past under different conditions; and I can, therefore, see no characteristics in the chemical composition of the rock to preclude the possibility of its deposition at a considerable distance from land. We are not, however, lacking in another criterion when the physical characteristics fail to be restrictive; the type of fauna represented is the safest guide in the interpretation of ancient regions of deposition. There is no region where muds are accumulating in the sea today, whether near shore or farther from land, where an abundance of organic remains is not being included. Along the entire Atlantic coast of North America the muddy facies of the littoral zone swarms with life, and while many of the species are confined to that facies it certainly cannot be claimed that where muds are accumulating there is a paucity of plant and animal life. Detailed studies of restricted areas of the ocean floor have proved that a large and varied fauna flourishes even where muds pour in in great quantities from the land. Thus, Walther (**295,** 36) has found that the muds in the Bay of Naples contain a fauna of about 1120 species of invertebrates and fishes. The fauna of the Bertie contains not two dozen species and nearly all of these belong to one phylum and to one class in that phylum, namely, the merostomes. Such a fauna cannot be considered as marine in any sense, if we accept the principles for the criteria of fossil faunas, based upon the study of recent faunas (p. 67 above). It is characteristic of no portion of the seashore, bays, lagoons, or estuaries, nor of the open sea, whether in the littoral belt or the deeper sea; such a fauna finds its counterpart in no waters of normal marine salinity, nor yet in those of modified marine salinity, either estuaries, epi-continental seas, lagoons, or other brackish to fresh water dependencies of the ocean. Thus, though we cannot determine with certainty the place of deposition of the muds from the chemical composition, or from other lithological characteristics, the fauna indicates with absolute certainty that those muds were not deposited in any portion of the sea.

From the foregoing discussion it appears that the Bertie waterlime is best interpreted as a deposit of clastic origin, and that the material was transported by rivers. It also appears that this material could not have been deposited in any part of the sea, for it has not the characters of non-terrigenous deep sea muds, nor the faunal content of a near shore, bay or estuarine deposit. There remains but one place for the deposition of these terrigenous muds and that is upon the land. There seems to be no escape from the conclusion that these lime muds of the Bertie represent the flood-plain or delta deposits from one or more rivers, or else that they accumulated as playa lake deposits. The characteristics of the sediments and faunas of such deposits have been fully described on pages 79-83, and it must be conceded that of all the known modes of deposition the lower flood-plain and upper delta regions of rivers come nearest in their physical and faunal characters to those found in the Bertie waterlime, though, of course, the nature of the sediment demands a source of supply in which calcareous material plays a dominant rôle.

It should be noted in this connection, that shallow water conditions of deposition for the waterlimes of New York and the associated calcilutytes (Manlius, etc.) are indicated by the occurrence of suncracked layers at several points. While these have not been found in the Bertie of the Buffalo region, they are wonderfully developed in the waterlimes of the Rosendale-Rondout regions, and in the Manlius of central New York and elsewhere.

Considering the waterlime as a flood-plain deposit, the history during Bertie time would be something like the following:

The early Siluric history of the eastern part of the North American continent had been admirably staged to lead up to the climax of waterlime deposition in many regions during the later Upper Siluric. During the Niagaran there had been a widespread advance of the sea which undoubtedly covered most of southeast and central Canada, as we may judge from the remnants still to be observed in the Lake

Temiscaming region and elsewhere. At the base of the series is the Clinton followed chiefly by shales and limestones representing the Rochester and Lockport, and finally by a dolomite. Since the sea in which these deposits accumulated was a transgressing one, it is apparent that in some sections the Niagaran deposits would overlap the late Ordovicic deposits and come to rest directly upon the crystallines of the Canadian shield. Furthermore, progressively higher members of the Niagaran would come to rest upon the old land as the Niagaran sea continued to spread. By the end of Lockport time, the greatest expansion was reached, and contraction of the sea set in, the Guelph dolomites being deposited in this more circumscribed sea. In some sections the change in deposition is inaugurated by the argillaceous beds of the Eramosa formation, and some of the late Niagaran beds are somewhat argillaceous. Beyond the farthest line of expansion of the Niagaran sea, the crystallines continued to form the rocky surface of the land. The contraction of the sea continued, until by the beginning of Salina time it had shrunk to such an extent that only a small epi-continental sea remained. It makes little difference whether we assume that this sea dried up entirely during the period when the salt formed in central and western New York and in Michigan, or whether we believe that the contracted remnant of the Niagaran sea persisted, the greater part of the North American continent is known to have become dry land during Salina time. Many writers have pointed out the evidences of arid conditions in the Salina, and I need not here repeat them. The entire country was exposed to drying winds, rain fell but seldom, and then it came as cloudbursts, filling river channels quickly and creating torrential streams of short duration. Whatever vegetation there may have been upon that ancient land was destroyed by the heat, and we may picture the country as a great desert where desiccation was in progress and where the winds and the rivers of flood seasons were the chief agents of transportation for the mechanically broken up rocks. The Salina was by no means a period of short duration; the thickness of the salt deposits alone shows that a long time was required for their formation. Throughout this whole period, disintegration of the Niagaran and earlier limestones was in progress, until there must have been piled up great limestone and dolomite dunes with fine beds of impure clayey material wherever shales were exposed to the clastation processes of the semi-arid climate. The crystallines likewise suffered the same destruction, and they added their quota to the materials which were blown about in one of the earliest deserts recorded in the history of the rocks. This desert differed markedly from all the large ones which are known to us at present, in having a predominance of carbonates instead of silicates in the "sand" grains. We must not, however, push the doctrine of uniformitarianism too far and insist that all the deserts in the past must have been composed of siliceous grains, because that is the rule in modern large deserts. On a small scale limestone deserts are forming now, and if large areas of limestones could be exposed in the arid regions of Africa or Arabia these limestone deserts would form on a vast scale. But there is now too much diversity in the rocks of the earth's crust, because throughout most of the world the continents have in large part been above sea level during the Tertiary and Quaternary, and erosion has been going on so that many types of rocks are exposed and particularly large areas of crystallines, and when any or all of these are brought under arid climatic conditions, grains of a great range in composition are exposed to the sorting action of wind. In the Middle Siluric of North America, on the other hand, a land area which had been covered by limestone was subjected to arid conditions, and there is no escape from the fact that dominantly lime grains were formed by the prolonged exposure during which mechanical processes alone were active, and decomposition played no part.

Succeeding the arid or semi-arid climatic conditions of the Salina was a period of greater rainfall and of expansion of the epi-continental seas. The rivers became permanent in response to the rains of a pluvial climate, and there followed upon the period of rock destruction in situ a period of transportation of material from the land into the sea. The prolonged disintegration of the limestones and dolomites with local shales had provided a vast soil covering which must have extended to a considerable depth, and which, because of fineness and friability could easily be removed by streams. Even the weakest little rivulet would be able to carry a small load of this material, which was so conveniently prepared. With the increased moisture in the air decay became active in further breaking down the mechanically disintegrated rocks, and in this way the igneous rocks that were exposed through erosion would yield a certain amount of silica and alumina as would also the shale bands in the limestones. Thus, while the rivers carried material which was dominantly calcareous or magnesian, certain impurities were also included. Some difficulty has been offered by the high amount of alumina, to account for which I offer the following suggestion. The only decomposition product in which alumina is higher than silica is laterite which might have been formed either during the Salina, to the north of the desert in which the limestones were disintegrating, or else during the Monroan when the arkoses previously formed by mechanical breaking up were subjected to decomposition. That the northeastern portion of Atlantica was of a more pluvial character than the northern part which supplied the lime mud is independently inferred from the character of the deposits formed in western Europe at this time. For here the semi-arid conditions existed on the *eastern* side of the highland which supplied the sediment, indicating that the moist region lay to the west, where the great southward flowing rivers of Atlantica appear to have had their source.

So far it has been shown that the Bertie waterlime is of clastic origin, and that the sediments were river-transported from the north. The fine stratification of the deposit and layers of sun-cracks in certain localities are structural features indicating that the muds were deposited in quiet waters, while the nature of the fauna has shown that the place of deposition could not have been in the sea, either far from shore, or in any protected, littoral portion; the only remaining place is on the land. In concluding this discussion, therefore, we may test the hypothesis of the flood-plain or delta origin of the Bertie by determining whether it accounts for all the facts. We are to imagine, then, two rivers flowing from the low-lying Canadian area southward until they empty into the slowly-advancing Upper Siluric sea. Marine deposition would be active to the south and if the rocks now covering the Monroan in southern New York and northern Pennsylvania were removed, we would expect to find the mixed marine and freshwater beds which marked the interfingering of the delta deposit with those that were laid down in the sea. Unfortunately, at present we know only the marine Monroan limestones from Pennsylvania, the position of that ancient strand-line being nowhere exposed. If we bear in mind the fact that the outcrop of the Bertie waterlime in New York forms only a narrow belt extending east and west, it is readily understood that the cross-sections of the two eurypterid-bearing "pools" are to be interpreted as cross-sections of the two north-south river channels (see figs. 3 and 4). The northward extension of those river courses has been removed by subsequent erosion, the southward continuation to the strand line is covered by later strata. If the Bertie waterlime of the two "pools" represents muds really deposited on flood-plains or the lower reaches of two rivers, then the lithological peculiarities of the deposit are readily explained. In that case we would expect these muds to become more marine southward, where they are now covered, and where the subaqueous delta part was situated. Between the deltas the Bertie should be impressed with certain marine characters, as it actually is in sections in Cayuga and Ontario Counties. In the Auburn-Geneva quadrangle, Cayuga County, the Bertie is an evenly bedded, impure, magnesian limestone, which when freshly broken is dark colored and of medium hardness. In portions it shows faint deposition lines, but heavier layers, from one to two feet thick, are usually quite compact. Some layers weather into a hard slaty shale. The fossils which have been found are: a few Lingulas, two species; one Orbiculoidea, a Rhynchonella, *Leperditia alta*, and fragments of eurypterids. In the Canandaigua-

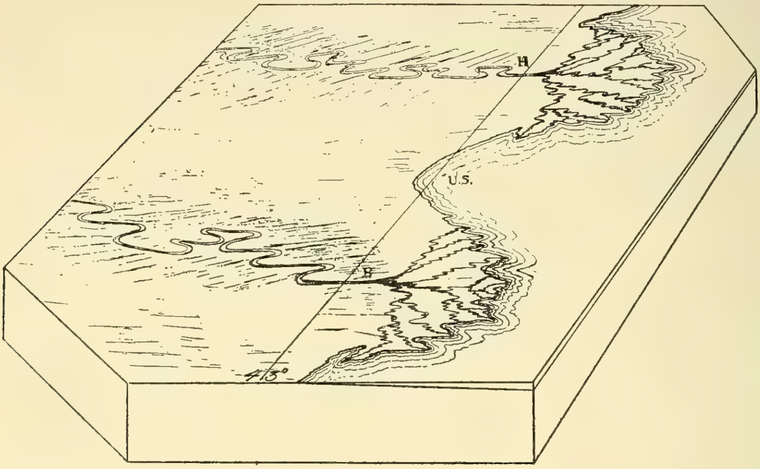

FIG. 3. BLOCK DIAGRAM ILLUSTRATING THE TWO PRINCIPAL DELTAS OF BERTIE TIME

B, Buffalo; U. S., Union Springs, H, Herkimer.

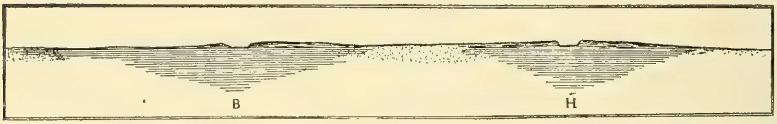

FIG. 4. CROSS SECTION (ON THE 43RD PARALLEL) OF THE BERTIE AND HERKIMER DELTAS

Naples quadrangle, Ontario County, the Bertie is a hard, dark, impure, hydraulic limestone, occurring in thick layers separated by thin seams of dark and apparently carbonaceous matter. The waterlime here shows a gradual transition from the Camillus. Fragments of eurypterid heads and appendages are not uncommon, and frequently *Leperditia cf. alta*, *Whitfieldella laevis*, and *Leptostrophia varistriata* occur. Yet the marine shells in both cases are seen to be of small specific gravity such as would easily be floated in across mud flats, and they evidently do not constitute a typical marine fauna since too few forms are represented. These occurrences of two or three species of brachiopods and of a crustacean in certain localities, far from proving that the Bertie as a whole was deposited in the littoral district of the sea, shows very clearly that the greater part of the waterlime was not deposited in any part of the sea and that only at intervals were a few marine organisms washed inland. Another significant fact that has already been referred to in connection with modern deposits is the separation of marine and fluviatile faunas in distinct layers. When river water meets with the invading tide, the current is checked and held back; this slack water is still fresh, and it deposits its load of mud and organic remains *above* the reach of marine waters. If marine currents later overcome the river currents and pass up the stream channel, marine organic remains may be deposited over the freshwater ones. Such lightweight structures as the exoskeletons of fluviatile crustacea and other arthropods are probably seldom carried out to sea against the opposing, denser salt water. If the eurypterids were fluviatile, the occurrence of their remains in abundance and well preserved in the regions where marine fossils are absent, and their scattered occurrence in the localities where a few brachiopods have been found is easily explained. Their entire absence from the Rosendale waterlime and the appearance of only a single specimen in the Rondout is likewise explained, since these deposits show a more marine character than does the Bertie of the Buffalo and Herkimer regions. The river portions of the Rondout and Rosendale either are not uncovered or else have been removed by erosion.

SUMMARY. The only available source of the lime in the Bertie is from the muds derived by the erosion of an older magnesian limestone, the Niagaran, or in some cases, perhaps, the Trenton. Where the Bertie is eurypterid-bearing, the rock was evidently deposited above sea-level, as a river flood plain and subaerial delta deposit. Southward and laterally the subaqueous part of the delta carries few or no eurypterid remains, but more marine organisms. That the Bertie eurypterids lived in the rivers is thus indicated, while their absence from the Rosendale could be explained by assuming that the present exposures of these rocks are in the more marine portion of the deposit. The relations are shown in the following diagrams (figs. 5 and 6).

6. THE KOKOMO WATERLIME

The Kokomo waterlime of Indiana is of very much the same character as the Bertie waterlime, showing the same thin laminations and fine texture. Throughout a limestone series forty feet thick thin waterlime layers occur and it is in these alone that the films of eurypterid exoskeletons are found. In the pure limestones a brachiopod fauna occurs, but no eurypterids are present; while in the separating waterlime eurypterids and ceratiocarids, but no brachiopods are found. Foerste has made the following statements in regard to the occurrence: "At the McReynold or Interurban quarry, in the southwestern corner of Kokomo, there is a much thicker exposure of the upper or brachiopod horizon. No merostomata have been found here.

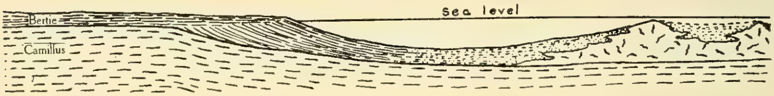

FIG. 5. IDEAL N. W.-S. E. CROSS SECTION FROM BUFFALO, N. Y. TO TYRONE, PA., SHOWING CONDITIONS DURING BERTIE TIME

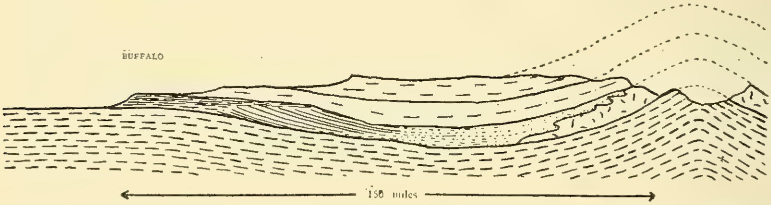

FIG. 6. GENERALIZED CROSS-SECTION OF THE SAME REGION SHOWING PRESENT CONDITIONS DUE TO POST-BERTIE DEPOSITION AND EROSION

"South of the center of Kokomo within the town limits, there is a deep quarry, covering a considerable area, where merostromata are common at an elevation of 3 to 3½ feet above the base of the quarry. This belongs to the lower thinly laminated part of the section, and the richly fossiliferous brachiopod beds appear to be absent" (Foerste, **67**, 7).

A section at the old George W. Defenbaugh quarry southeast of Kokomo, Indiana, shows the exact relation between the eurypterid-bearing layers and the brachiopod bed (**67**, 7).

	FEET	INCHES
Heavy bedded fossiliferous limestone	1	8
Chert, thin, bedded, with ostracods		1
Thin bedded fossiliferous limestone	2	
Base of brachiopod horizon		
Darker layer of limestone		2
Thin bedded limestone		10
Heavier bedded limestone, but thinly laminated	1	4
Thin bedded limestone		9
Darker limestone		3
Layer with merostomata		

The line of reasoning which was adopted to show that the Bertie was a clastic, river-borne deposit which was spread out on the land

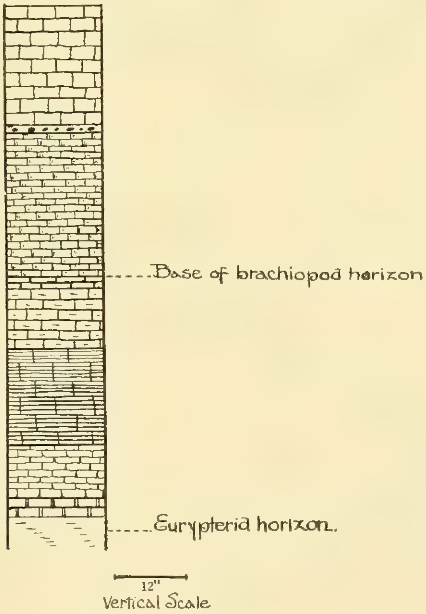

Fig. 7. Section Southeast of Kokomo, Indiana, Showing Distinctness of Brachiopod and Eurypterid Horizons
(Data from Foerste)

can be followed through in the same way for the Kokomo, the most marked difference between the two formations being the local character and diverse source of the latter. The Kokomo waterlime lacks the lateral and vertical persistence characteristic of the Bertie and in this respect is similar to the waterlimes of Oesel which in many outcrops appear as thin bands intercalated between limestone beds (see section, fig. 7 above, and description). Indeed, the section revealed at Kokomo is the counterpart of what theoretically we should expect to find in the southward continuation of the Bertie in Pennsylvania where the waterlimes merged into the marine deposits.

The second difference between the Kokomo and Bertie waterlime is that of origin, for while the latter was derived from the north the former must have come from the west since the sea covered the Michigan area during Monroe time and precluded the derivation of sediments from the Canadian region. It is difficult to arrive at an explanation of the lithogenesis of such a formation when so few outcrops are visible, but yet we can determine enough to show that the Kokomo sediment was river-borne and came from a continent to the west (see map, fig. 8). A study of the faunas convincingly shows the distinctness of the source of the material and organisms found at Kokomo (see below, pp. 253-256).

7. THE TARANNON-WENLOCK BEDS OF SOUTHERN SCOTLAND

Distribution of Formations. The clearest conception of the lithogenesis of the eurypterid-bearing Wenlock beds of southern Scotland is to be obtained from a survey of the palaeographic conditions existing in Great Britain from the end of Ordovicic time on through the Siluric. The outcrops in Wales, in the hilly areas of Cumberland and in innumerable outliers in Westmoreland and elsewhere, as well as those of the southern uplands of Scotland, indicate that throughout the Ordovicic the sea covered Wales, the greater part of western and central England and southern Scotland as far north as the great northeast-southwest fault line delimiting the northern edge of the tableland. The central and northern portions of Scotland formed a part of the old land which, rising to the east in the Scandinavian shield, extended westward through North Britain and Ireland on into the northern Atlantic, and which throughout the Palaeozoic furnished the sediments which were deposited either in the sea to the south of that ancient shoreline, or on the land to the north of

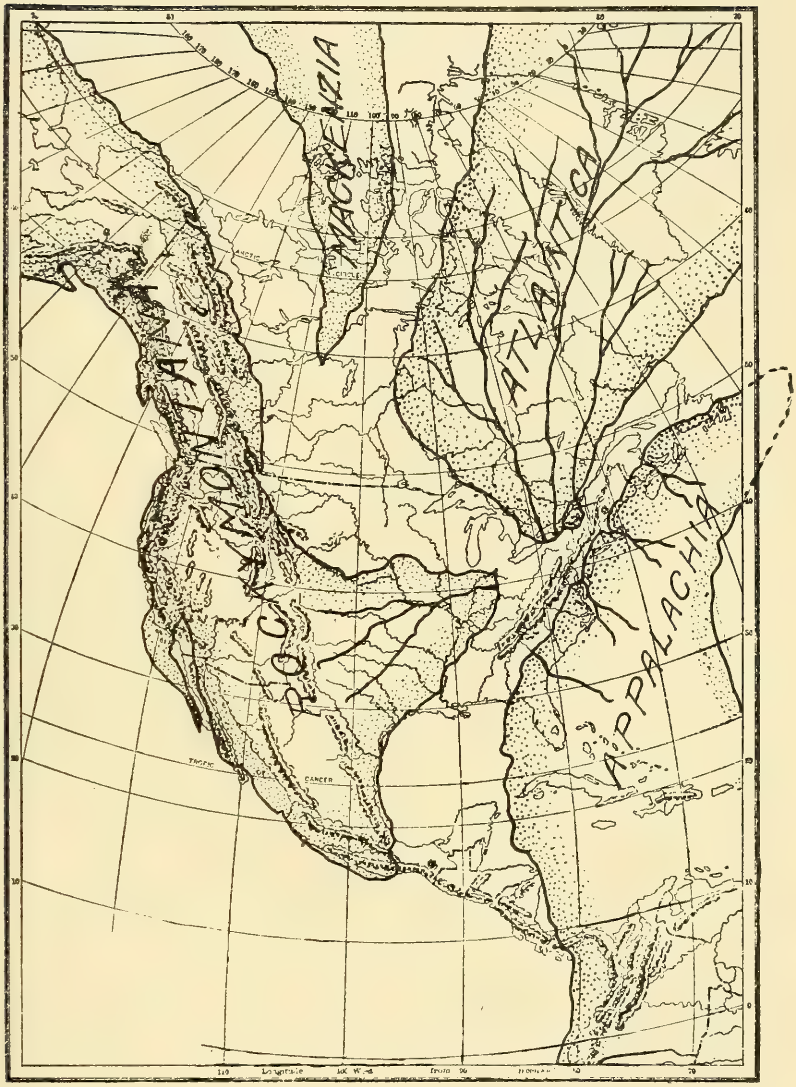
MACKENZIA
ATLANTICA
APPALACHIA
ARCTIC CIRCLE
TROPIC OF CANCER
Longitude West from Greenwich

Fig. 8. Palaeogeographic Map of North America During Bertie Time (Grabau)

it. While the faunas and the lithological deposits in England and Wales indicate, with few exceptions, the prevalence throughout the Ordovicic of open marine conditions, in southern Scotland, on the other hand, the record is one of oscillations, showing now the prevalence of terrigenous deposits, again that of sea-derived or thalassigenous deposits.

A rapid survey of the succession of events during Ordovicic time shows that there was a gradual retreat of the sea towards the south and southeast during the middle and upper Ordovicic and the lower Siluric, followed by a widespread advance during Wenlock time. A few of the typical sections will readily bring out these facts (see also the general description of the region on p. 151).

The Ordovicic and Siluric rocks of the Southern Uplands of Scotland are exposed in a series of belts trending northeast-southwest. The southernmost is a rather narrow, discontinuous strip composed of Wenlock and Ludlow flaggy grits and mudstones, bordering the northern coast of Solway Firth and extending northeast into the Cheviot Hills. The second belt, from 20 to 25 miles wide extends from St. Abbs Head on the east coast, through the Lammermuir Hills across the greater part of Selkirk, Peebles, Dumfries, Kirkcudbright and Wigtown (see map). This band consists of the Lower Siluric Llandovery and Tarannon beds. The third belt, narrow in the east where it does not quite reach the coast, but constituting the northern slopes of the Lammermuir Hills, broadens westward until it becomes 15 or more miles wide. It consists of Llandeilo and Caradoc limestones with a large amount of radiolarian chert of Arenig (Lower Ordovicic) age. The northwestern termination of this belt is the Girvan area with its great development of Arenig volcanic rocks. From 5 to 10 miles north of the third belt are two important regions one in the Pentland Hills, Edinburghshire, the other in Lanarkshire, where the Wenlock, Ludlow and Downton beds are exposed as inliers in the Old Red sandstone. The relation of these isolated Siluric outcrops to those of the southern tableland will be made clear by a consideration of the tectonic arrangement.

Towards the close of the Lanarkian a pronounced uplift took place accompanied by a tremendous amount of lateral compression giving a great series of folds whose axes run northeast-southwest, parallel to the major axis of the tableland. Denudation set in before the beginning of Old Red deposition so that the Old Red rests unconformally upon Siluric or Ordovicic beds. Moreover, formations which were continuous at the time of deposition now appear in far separated localities. Over the whole of this much folded and faulted series the Old Red sandstones were deposited by the rivers flowing south from the northern Highlands. Subsequent erosion has carried away large portions of these Devonic beds, and has cut down into even the lower rocks, so that the Ordovicic and Siluric are exposed in broad belts as shown above, while in certain places only inliers in the Old Red have as yet been exposed. To this class belong the isolated outcrops in the Pentland Hills and in Lanarkshire. It is thought that in all probability the Wenlock and Ludlow in those regions were continuous and extended southwest into Ayrshire and northeast into the Lothians.

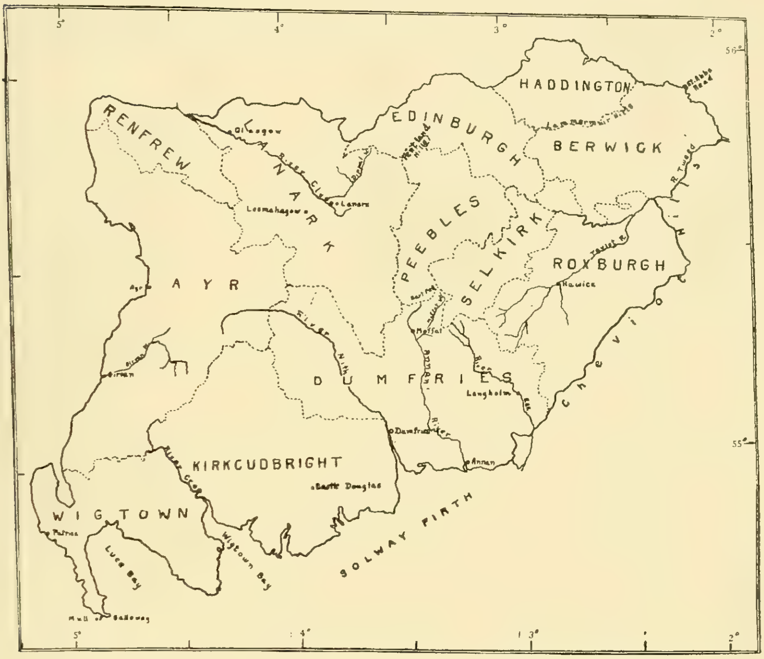
5°
4°
3°
2°
56°
55°
HADDINGTON
St. Abbs Head
Lammermuir Hills
EDINBURGH
Pentland Hills
BERWICK
R. Tweed
RENFREW
Glasgow
LANARK
River Clyde
Lanark
Lesmahagow
PEEBLES
SELKIRK
ROXBURGH
Teviot R.
Hawick
AYR
Ayr
Girvan
River Nith
Moffat
River Annan
River Esk
DUMFRIES
Langholm
Dumfries
Annan
Cheviot Hills
KIRKCUDBRIGHT
Castle Douglas
River Cree
WIGTOWN
Portpatrick
Luce Bay
Wigtown Bay
SOLWAY FIRTH
Mull of Galloway

FIG. 9. SKETCH MAP OF SOUTHERN SCOTLAND INDICATING LOCALITIES FOR ORDOVICIC AND SILURIC EURYPTERID-BEARING HORIZONS

THE LLANDOVERY-TARANNON. In the lowest Ordovicic, volcanic activities were pronounced in the Girvan area, but throughout the central and northern belts of the tableland open marine conditions prevailed, marked either by submarine volcanoes or by the accumulation of radiolarian ooze, but the presence of fossiliferous mudstones in the northern belt of Arenig rocks indicates that the shore was not far distant. There is evidence that during Llandeilo time conditions were less stable in the northern area, for the black graptolite-bearing Glenkiln shales (Upper Llandeilo) often merge laterally into greywackes and grits, while sometimes, as for instance in sections at the headwaters of the Girvan River, the Glenkiln fossils occur in "minute dark seams in sandy shales, embedded in massive greywackes and grits" (Peach and Horne **215**).

The section which is most complete, showing no disconformities and indicating, therefore, continuous deposition, is that at Moffatdale about 10 miles to the northeast from Moffat, where in the famous Dobb's Linn anticline studied by Lapworth, the succesions given in the first column, figure 10, is shown. It will be seen that the Glenkiln and Hartfell groups (Llandeilan and Caradocian, respectively), are complete and that the latter is followed by the Birkhill shales (Llandovery) which end with the *Rastrites maximus* zone (b3), which in turn is conformably followed by the green and grey shales of the Lower Tarannon. Crossing the strike to the northwest for about five miles, the Hartfell section is met with. It is the type locality for the shales of that name. The succeeding Birkhill shales are found to go no higher than the *Monograptus gregarius* zone (a3), which is conformably followed by the Tarannon grits. The signifi-

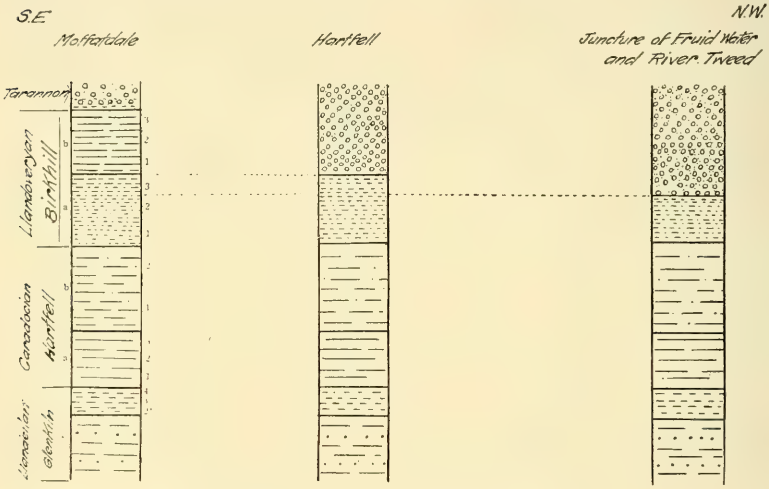

FIG. 10. COLUMNAR SECTIONS OF ORDOVICIC IN MOFFAT DISTRICT, SCOTLAND

cance of this succession will be spoken of presently. Continuing at right angles to the strike, there is found about 2 miles northwest of Hartfell on the Cow Linn, the last outcrop of the *Monograptus gregarius* zone. Only 3½ miles northwest of this locality, near the junction of the Fruid water with the River Tweed the *gregarius* zone is no longer to be found, the highest of the Birkhill beds being the *Diplograptus vesiculosus* zone (a2) which is the second in the Lower Birkhill series. This zone is immediately followed by the Tarannon grits. As the last of the Llandovery outcrops are traced towards the north, fossils become very rare indeed and, although towards the boundary line of the northern and central belts no specimens of *D. vesiculosus* or of *D. acuminatus* have been found, a few other graptolites which along the valley of the Tweed are associated with these zonal fossils, have been encountered. It is thus seen that within the remarkably short distance of 9 miles,[6] as traced from the Dobb's Linn anticline to the Llandovery-Tarannon border, the whole of the Upper and nearly all of the Lower Birkhill shales have disappeared, the fossils becoming rare even in the shale members which are found, and, most significant of all, the Tarannon grits or conglomerates everywhere follow upon whatever member of the Birkhill group forms the top of the section.

Such a stratigraphic relation might be interpreted in one of two ways. On the one hand it might be supposed that the Llandovery sea retreated to the southwest and that dry land conditions accompanied by subaerial denudation obtained in the areas laid bare. This would imply that more of the Birkhill shales had been deposited to the northwest of Moffatdale than are now seen in the sections and that the present exposures represent merely the parts which have not been touched by erosion. The Tarannon would then represent the river deposits spread out upon the eroded remnants of the Llandovery. That such is in all probability not the case is indicated by the statement made by Peach and Horne that in the Hartfell section (in the Frizzle Burn) "the black shales and mudstones of the *Monograptus gregarius* zone pass conformably upwards into the massive grits of Tarannon age without any representative of the Upper Birkhill Shales" (P. and H. **215**, 133). The significant word is *conformable.* If the contact is conformable there was no erosion, and therefore it is not likely that two miles distant there was any considerable erosion. Thus another interpretation is called for. The facts, and they have been gleaned from a detailed study of many more sections than can be mentioned here, lead to the conclusion that there was no erosion between the deposition of the last of the Llandovery (Birkhill) beds, whether they were Lower or Upper Birkhill, and the lowest Tarannon beds. The structural relation is, therefore, one of replacing overlap, the Tarannon beds pushing to the southeast just as rapidly as the graptolite-bearing Llandovery muds retreated in the same direction. Lines of sections at right angles to the strike of the Llandovery and Tarannon rocks taken in various places from coast to coast, indicate that in the northern part of the central belt the Tarannon is always of a massive unfossiliferous character, grading southeastwards into graptolite-bearing shales and mudstones. There is no doubt that the coarse conglomerates and grits were river-borne. In one of the typical localities in the Moffat district Peach and Horne, in describing the conglomerate say, "the rock possesses a greywacke matrix, in which are embedded rounded pebbles of quartz, red chert with radiolaria, Arenig volcanic rocks, with boulders of granite and quartzite from eight to ten inches in diameter. Some small pieces of mica schist have also been observed. The fragments of quartzite and mica-schist resemble rocks of those types in the Eastern Highlands; there can be little doubt that they were derived from that region" (P. and H. **215,** 210). These authors also note in regard to the greywackes and grits that, "both volcanic and plutonic rocks have contributed to their formation. The fragments are angular or subangular. Well-rounded grains are rare. There is, further, a very great variability in the sizes of the constituent grains; indeed, the material does not appear to have been well sorted by aqueous action" (**215,** 211). It seems surprising that materials which had been transported by rivers for so great a distance, it being about one hundred miles from the Eastern Highlands to the Moffat district, should not be better sorted. However, it is clear that the material must have been brought down by rivers. That it was deposited as a subaerial delta or series of deltas which spread out into the sea to the southwest is suggested by the character of the materials, for in the extreme north of the Tarannon area there are only the coarse conglomerates without fossils, but these deposits merge ever so slowly into finer ones southward, the first change in the conditions of sedimentation being indicated by the intercalation of thin, leaf-like beds of shales bearing graptolites. Indeed, this domination of terrestrial over marine sediments is seen even towards the close of the Llandovery in many regions. In the northeastern portion of the Central Belt in the basin of the Gala Water, the various Birkhill zones are separated from each other by thick beds of grits, conglomerates, and greywackes. Even the graptolites show the effects of the great inpouring of fresh water, for not only are they rare, but those which are found are dwarfed as would be expected of a fauna dwelling in brackish water. Such features point beyond a doubt to the oscillatory conditions which prevailed along the shoreline and just so far as those conditions can be traced southward so far may we say the sea retreated in Llandovery and Tarannon time. It is only along the south central portion of the southern margin of the Central Belt that the highest Tarannon rocks are found; their continental origin is undoubted. They are unfossiliferous except for tracks and trails and they consist of grey, green, and red shales with bands of conglomerates one or two feet thick. All of these facts indicate a lithological replacement of marine by terrestrial deposits along a northwest-southeast line. The faunal replacement is equally striking. Along the northern border of the Tarannon belt the coarse deposits contain no fossils, but tracks and trails; when a few dark shale bands appear, they usually contain not good zonal fossils but a mixed Llandovery and Tarannon fauna. *Monograptus exiguus* is recognized as the lowest graptolite in the Tarannon and yet it frequently occurs with *Rastrites maximus* and *Climacograptus normalis*, the former of which is the zonal fossil for the uppermost Birkhill, and both of which are typical Llandovery forms. Towards the south, however, this interfingering and mingling of faunas is no longer noticeable and the Tarannon passes into the shaly, mudstone phase where zonal graptolites are well recognized, though in the passage to the upper Tarannon the mud facies is again replaced by conglomerates. The evidence supplied by the lithological and faunal characteristics, each taken independently, points conclusively to a replacing overlap and to the terrestrial origin of the Tarannon. The facts may be set forth in a generalized section.

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[6] The distance would, of course, be much greater were the folds eliminated.

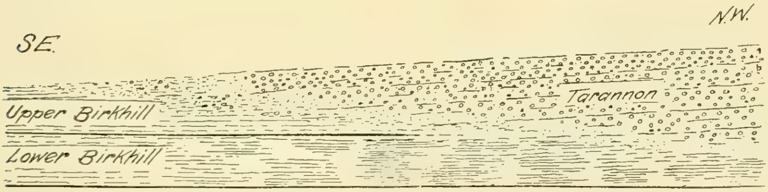

FIG. 11. IDEAL SECTION SHOWING RESTORATION OF CONDITIONS DURING LLANDOVERY-TARANNON TIME IN SOUTH SCOTLAND

It is readily seen that a startling conclusion must be drawn from the data, namely, that the Llandovery is not a time period separate from the Tarannon, but that the two are synchronous, the Llandovery being equal in age to the lower Tarannon and appearing as a wedge which widens southward till it reaches its maximum thickness of 96 feet in the Moffat region. The Llandovery is a black mud facies containing a mixed Ordovicic and Siluric fauna, the evidences of the presence of the latter being indicated by the numerous species of Monograptus, the Ordovicic aspect being supplied by the Didymograptus species.

The terrestrial origin of the Tarannon has been shown by two different and mutually independent lines of evidence. It is of interest, then, to find in the Upper Tarannon the fragment of a eurypterid. Near the southern border of the Central Belt just south of Bowden which is northeast of Selkirk, there is recorded the occurrence, in the grey blue shales and flagstones probably of the Hawick series, of the telson of Eurypterus and a fragment of Dictyocaris associated with crinoid stems. The typical Hawick rocks found in the neighborhood of Selkirk and further south at Hawick are themselves barren of all fossils but trails, burrows, and tracks. Near Selkirk Crossopodia and Myrionites have been found, while at Hawick Protovirgularia, Crossopodia, Menertites, Nereites and other tracks are abundant and the body segments of a Ceratiocaris have been found. The occurrence of the single eurypterid fragment in this great barren series is difficult to explain as a marine organism. It may be argued that the presence of crinoid stems is clear enough evidence of the marine nature of the deposits, but such disjointed stems might be washed out from an earlier deposit or even if of the same age as the eurypterid it is well known that those joints are swept great distances from the original habitat of the crinoids, and that they might be washed far inland on low-lying flats along the shore. At any rate, the single eurypterid remain fails to prove anything definite; it might be washed in from the sea, but then one must ask why the eurypterids are not found in the Tarannon muds in the regions where abundant graptolite faunas have been found. The fluviatile origin of the Tarannon has been amply shown, and it is easy to understand on the supposition that the eurypterids were living in the rivers, that fragments of the exoskeletons should be washed out from time to time. It may here be suggested that a further careful search in the Tarannon rocks might well yield a eurypterid fauna as fine and as unexpected as the fauna in the Shawangunk conglomerate. It is also not improbable that some of the tracks reported from the Hawick rocks were made by eurypterids, an interpretation in keeping with Patten's suggestion for the origin of Climatichnites (Patten, 206).

Following the retreatal phase of the Llandovery and the succeeding terrestrial phase of the Tarannon are the Wenlock beds. Though now exposed only in the southern belt below the tableland, in the small inliers in the Pentland Hills and Lanarkshire, and in the Girvan area, there is little doubt that the Wenlock at the time of its deposition extended entirely across this area. Such being the case, it represents the deposits of the advancing Wenlock sea. Continuous sections from the Tarannon into the Wenlock at various places in the belt south of the tableland show that the succession is conformable, thus proving that the line marking the end of the retreat of the sea must be northwest of this band and would lie, therefore, in the region of the tableland from which all Wenlock strata have, unfortunately, been removed. It is probable that the Tarannon-Wenlock shoreline was in the central or southern portion of the central belt. One of the finest exposures of the conformable contact of the Wenlock on the Tarannon is at Burrow Head, the outermost extremity of land between Luce and Wigtown bays just north of Solway Firth. The nature of the sediments along the belt south of the tableland indicates that oscillatory conditions prevailed, the seafloor being covered at times with fine muds, at others by coarse conglomerates. One would have expected that terrigenous deposits would have played a less important part there than in the Pentland Hills which are known to have been nearer the old shoreline. It is not unlikely that the land may have projected southward in a peninsula which lay between the present sites of Lanarkshire and Girvan, thus bringing the terrigenous sediments further south. In the southern belt there has been recorded a single occurrence of a eurypterid remain, so incomplete and so poorly preserved that it is specifically unidentifiable. Four miles south of Hawick at the junction of a small tributary with the Slitrig water Eurypterus sp. is reported associated with *Ceratiocaris papilio* and a number of graptolites. This type of occurrence, namely of a single eurypterid fragment associated with well-preserved abundant remains of marine organisms, has already been mentioned several times, and its significance pointed out. A general summary will be found below on page 194, in which the argument for the marine habitat of the eurypterids based upon such evidence is dealt with and, I trust, demolished for all time.

From the point of view of the determination of the habitat, we come now to the most significant occurrence of eurypterids thus far known in the British Isles. To be sure the "seraphims" of the Old Red Sandstone discovered by the stone-cutter of Cromarty and proclaimed by Agassiz to be "the remains of a huge lobster," are deservedly famous. Their size, abundance, association with the monster cephalaspid fishes, and above all the mystery attending their place in nature have shed upon the eurypterids of the Old Red Sandstone a picturesque and historical glow which makes the later discoveries of faunas merely so many cold triumphs of science. But the light which the Devonic merostomes throw upon the solution of the problem of the habitat cannot compare with that which emanates from the fauna of the Wenlock. And the reason is this: A large number of geologists have already come to the conclusion that the Old Red Sandstone was a series of torrential and flood plain deposits, in which case they can hardly fail to believe that the organisms found in the deposits were river-dwellers. Furthermore, it will not be a very difficult undertaking to convert the unbelievers in the river origin of the Old Red to staunch advocates of it. In fact, we may say that the case is so clear not only as to the lithogenesis of the deposits of the Old Red Sandstone, but also as to the medium in which the organisms of that time must have lived, that a few years' from now there will probably not be any thoughtful geologist who will not agree that the Devonic rivers supplied the sediments and were also the home of the Old Red fishes and merostomes. But in the case of the Wenlock it seems the rankest heresy to say that any of the organisms whose remains are found therein could be other than dwellers in the sea. The majority of palaeontologists would describe the Wenlock as exposed in the inliers north of the tableland in some such manner, "The Wenlock consists of a series of conglomerates, mudstones and grits with intercalated shale bands which are usually highly fossiliferous. While the coral fauna so characteristic of the Wenlock of England is lacking, there abounds, nevertheless, a representative marine assemblage which includes graptolites, brachiopods, pelecypods, gastropods, cephalopods, crustacea, and eurypterids. The merostome fauna is one of the largest known from a single horizon, comprising sixteen species, distributed in five genera, while the remains are so abundant that certain layers are almost like coal beds, they are so charged with carbon." Who, indeed, would have the temerity to claim that such a fauna of eurypterids with such associates could lead to any other conclusion but that the eurypterids dwelt in the Wenlock sea? It is just because such a conclusion in reality is entirely unjustifiable that I was led to state at the beginning of this paragraph that the eurypterid occurrence in the Wenlock is the most significant one in the British Isles when its interpretational value is taken into account.

WENLOCK OF THE PENTLAND HILLS. The Pentland Hills are formed from a series of the folded pre-Devonic beds and are completely surrounded by the various sub-divisions of the Old Red sandstone and by the igneous rocks. The Siluric rocks are exposed in four small isolated patches in these hills, and yet in spite of the small size of the outcrops and their isolation they have yielded more species of eurypterids than any other single formation in the world, with the exception of the Bertie waterlime, though there is this marked difference between the two faunas: whereas the Bertie fauna contains the most perfectly preserved individuals that have yet been recorded from any locality, with the exception of those from Oesel, the Pentland Hills fauna, on the other hand, is made up, for the most part, of fragmentary individuals.

The most important of these four inliers is that extending from the head of Lyne water to the head of North Esk River, a distance of about three miles. Although this inlier is the largest of the four it covers an area of only about two to three square miles. A number of excellent sections have been opened up by the North Esk and its various tributaries. The river itself cuts across the outcrop nearly at right angles, and since the beds here as in the other inliers are strongly folded, standing on end with the strike northeast-southwest, a considerable range in age is shown in the section, the lower beds appearing to the east, in the North Esk section where the Wenlock, Ludlow and a portion of the Lanarkian (Downtonian) are exposed, while to the west the Lyne water cuts through the passage beds or Downtonian. Of the numerous sections thus exposed the one which has now become most famous on account of the large eurypterid fauna discovered there by Hardie and Malcolm Laurie is that on the Gutterford Burn, a small tributary of the North Esk. (See map, fig. 12.) On the east bank of the burn, about a half a mile up from the North Esk Reservoir the strata consist of "flaggy micaceous greywackes" dipping at about 80 degrees to the southeast. Peach and Horne give a list of the fossils which they state come "from this band" (**215,** 593), but one may question the accuracy of this statement when com-

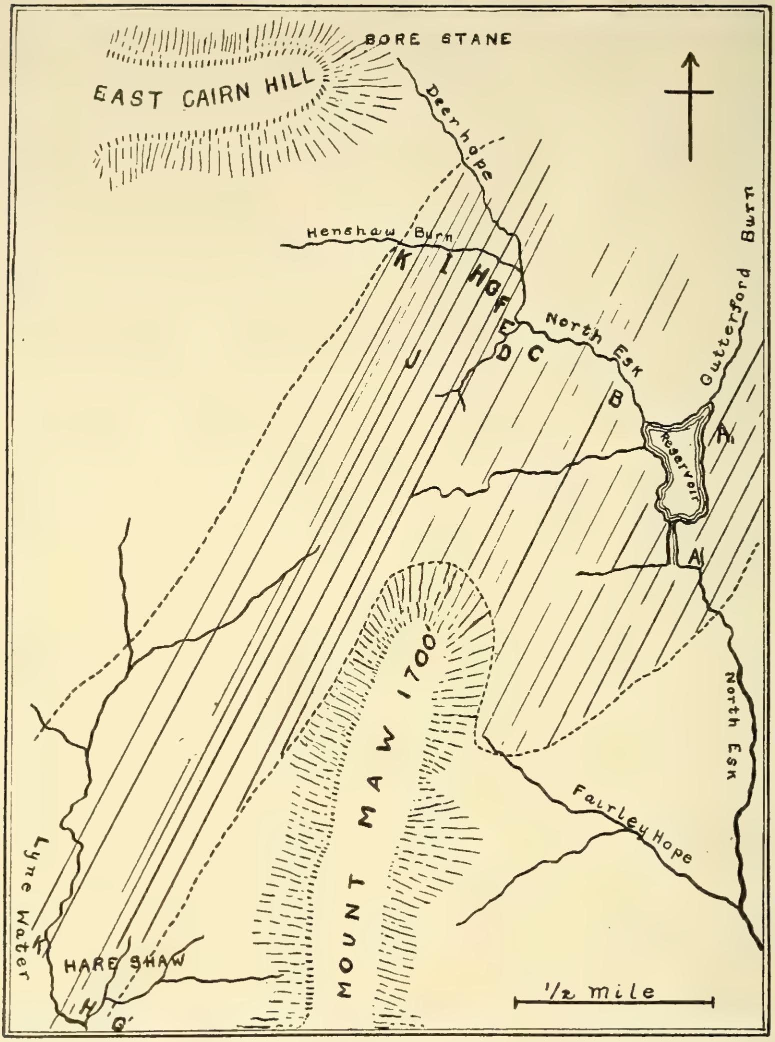
BORE STANE
EAST CAIRN HILL
Deerhope
Henshaw Burn
K I H G F E D C B A A
North Esk
Gutterford Burn
Reservoir
MOUNT MAW 1700'
North Esk
Fairley Hope
Lyne Water
HARE SHAW
H' G'
½ mile

Fig. 12. Sketch Map Giving Outcrops of the Wenlock of the Pentland Hills, Scotland
(After Henderson and Brown)

pared with that made by Laurie at the time when he described the eurypterid fauna from these beds. He says: "The rock in which the Eurypterids are preserved is an irregularly fissile fine-grained sandstone, containing a considerable amount of carbonaceous matter distributed in thin layers. The only other recognizable fossil which occurs in the rock is the so-called *Dictyocaris ramsayi*, which occurs in considerable abundance" (**145**, 151). If one searches in the literature back to the time when eurypterid remains were first found in the Pentland Hills, one comes upon a description which is in but poor accord with the most recent one, emanating from the Scottish Survey, although bearing out quite well the statement made by Laurie. John Henderson in 1880 read a short account before the Geological Society of Edinburgh of some fossils which he had discovered in the Pentland Hills, in the beds in the Gutterford Burn. A few extracts from his paper will serve to give the clearest description which I have yet found of the eurypterid-bearing band. "This bed, which is upwards of a foot in thickness, is mostly made up of what I consider to be a mass of vegetable matter, along with an organism which has been described and figured by Mr. Salter . . . . as a large phyllopod crustacean under the name of *Dictyocaris ramsayi* . . . . there is in this bed a large amount of vegetable matter, some of the plant remains showing about one-tenth of an inch of carbon on the surface, and these plant remains are so associated with the supposed crustacean remains that it is difficult to determine the one from the other. I am now inclined to believe that the Dictyocaris is of vegetable origin. The fact of finding plant remains in such abundance in the Silurian rocks is, as far as I am aware, a new feature, as until lately true plant remains in that formation were considered doubtful. But there can be no mistaking their character and abundance in this bed, which is so thickly charged with carbon that it looks like an impure bed of coal . . . . the remains of undoubtful crustaceans of the genera Eurypterus and Stylonurus in a fair state of preservation occur in the same bed with the Dictyocaris and plant remains . . . . the bed in which these specimens are got must be at least as low as the Wenlock Shale. It lies several hundred feet below the fossiliferous bed in the North Esk above the reservoir, which is of undoubted Wenlock age" (**115**).

We do not know precisely the exact relation between the eurypterid-bearing bands and the beds containing the other fossils, but all available evidence indicates that they are not identical. Considering the decidedly different facies associated with the eurypterids and with the remaining fossils it seems probable that the former are confined to certain bands or lenses, as is often stated. In any case their occurrence is still capable of easy explanation whether they are actually in the same beds and really closely associated or whether they are found only along certain partings as is indeed indicated by Peach and Horne who say that "A characteristic feature of this eurypterid bed is the abundance on the divisional planes of that enigmatical fossil *Dictyocaris ramsayi*, forming, indeed, large black patches about an inch and a half across." One fact at least is clear: The eurypterids occur in a very thin band and are found in abundance in one section only, while a few fragments are found in one or two other nearby localities. The eurypterids are confined within a few inches vertically, while laterally the remains have a very limited extent, disappearing within a few yards. The occurrence at Gutterford Burn is in bed A of Brown and Henderson which contains ten species. Two species have been recorded from bed H to the northwest in a section exposed by the Henshaw Burn, a tributary of the North Esk. Except for these two isolated occurrences no eurypterids are found in the other beds or even in the same beds as they are traced along the strike. The remains of sixteen species representing five genera appear suddenly in a band a few inches thick, without forerunners in the underlying beds and with not a single straggler in the immediately overlying beds.

The following species of merostomes have been obtained from Gutterford Burn according to the identifications made by Malcolm Laurie (Peach and Horne, **215,** 132, 593, 594):

Bembicosoma pomphicus Laurie
Stylonurus (Drepanopterus) pentlandicus (Laurie) emend. Clarke and R.
S. (Drepanopterus) bembicoides (Laurie) emend. Clarke and Ruedemann
S. (Drepanopterus) lobatus (Laurie) emend. Clarke and Ruedemann
Eurypterus conicus Laurie
E. minor Laurie
Eusarcus scoticus (Laurie) emend. Clarke and Ruedemann
Eurypterus 3 sp. undet.
Stylonurus elegans Laurie
S. macrophthalmus Laurie
S. ornatus Laurie
Slimonia dubia Laurie
Dictyocaris ramsayi Salt
Palaeophonus loudonensis Laurie

In beds of the same series in this section the following marine organisms have been obtained, according to Peach and Horne:

Amphispongia sp.
Nidulites favus Salt.
Dictyonema venustum Lapw.
Dictyonema (Chondrites) verisimile Salt.
Cyrtograptus murchisoni ? Carr.
Monograptus priodon Bronn.
Monograptus vomerinus Nich.
Favosites sp.
Tentaculites tenuis Sow.
Palasterina sp.
Crinoid fragments.
Lingula lewisi Sow.
Lingula symondsi Salt.
Strophomena walmstedti Lindst.
Euomphalus rugosus Sow.
Conularia monile Lindst.
Conularia sowerbyi Def.
Conularia sp.
Orthoceras angulatum Wahl.
Gomphoceras ellipticum ? M'Coy

The form described as *Bembicosoma pomphicus* is somewhat problematical and may be more nearly related to Hemiaspis than to the eurypterids. Of special interest is the finding of a scorpion in these beds. There is only one specimen of *Palaeophonus loudenensis* and this is in a bad state of preservation so that it is impossible to tell whether this early scorpion was aquatic and gill-bearing, or terrestrial. Drepanopterus is a new genus founded by Laurie for the three species: *pentlandicus*, *bembicoides*, and *lobatus*, but they are all described from imperfect material; the first from a fairly good specimen, the other two from a few slightly better.[7] Laurie's genus Bembicosoma[8] with the one species pomphicus was established for a few rather good fragments, which, however, were only doubtfully identified. *Slimonia dubia*, also described by Laurie, is but poorly represented, as are likewise the three species of Stylonurus: *elegans*, *ornatus* and

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[7] Clarke and Ruedemann have placed Drepanopterus as a subgenus of Stylonurus.

[8] Laurie originally spelt the name Bembycosoma and the species of Drepanopterus, bembycoides, but in the corrigenda to his 1900 paper, p. 590, (147) he called attention to the proper form Bembicosoma and bembicoides, a change which has not been noted by later authors.

macrophthalmus. Imperfect remains are all that have been found of the five species of Eurypterus: *scoticus*, *punctatus*, *minor*, *cyclopthalmus* and *conicus*.

In the Girvan area near Straiton where continuous marine, though near-shore deposition was going on through Tarannon on into Wenlock time, the strata are found to be highly fossiliferous at certain horizons and graptolite bands are well made out. Collections made in a quarry near Blair Farmhouse not far from the village of Straiton have yielded a number of fossils, among which is a Eurypterus sp. Owing to the fact that British geologists seldom state the exact horizon at which fossils are collected, and of course this is often difficult to do when the strata stand on end and break off in slabs from which collections are made, it is impossible to say whether the eurypterid occurred in a seam with the crustacea while the undoubted marine forms occurred in other seams, as is found so often to be the case. The list given by Peach and Horne is merely quoted as coming from this quarry (**215,** 549).

Eurypterus sp.
Beyrichia kloedeni (M'Coy)
B. impendens (Jones)
Entomis globulosa (Jones)
Monograptus galaensis (Lapw.)
M. priodon (Bronn)
M. riccartonensis (Lapw.)
M. vomerinus (Nich.)
M. sp.
Retiolites geinitzianus (Barr.)
Favosites sp.
Lingula symondsi (Salt)
L. sp.
Orthis sp.
Siphonotreta anglica (Morris)
Cardiola fibrosa (Sow.)
Bellerophon sp.
Orthoceras subundulatum (Portl.)

After this rather careful study of the occurrences in the Wenlock, we are in a position to form a valuation of the hypothetical description of this formation and its fauna, which I gave on page 130 above, and which may be fairly taken as the prevalent view expressed in textbooks and by authors generally. The main statement that is dwelt upon insistently, and which is so dangerously plausible, is that in the Wenlock the eurypterids are found in an undoubted marine formation in association with typical marine fossils. Such a statement is full not of truths, but of half truths, and these are far harder to combat than actual untruths. In the present instance we have only to consider how much weight would attach to such a statement if the following significant bits of information were added: (1) The eurypterids do not occur in the same beds with the undoubted marine forms, but always in certain leaf-thin bands which carry no other fossils except *Dictyocaris ramsayi*, a form which may be a fluviatile if not a terrestrial plant or animal, but the systematic position of which is at present wholly undetermined. The thickness of all the beds containing the eurypterid-bearing bands is only one foot; it is a grit and greywacke; the typical marine fossils are found in the shales and in limestone lenses. (2) Not a single complete eurypterid has been found among the hundreds of specimens collected and the very species described by Laurie have usually been founded upon fragments. (3) The exoskeletons have not only been dismembered—this might be expected in any case, for during the process of decay the various members might fall apart and thus be embedded in the mud, few complete individuals being entombed—but the fragments are macerated, the edges are broken and worn, the surface sculpturing indistinct, altogether showing evident signs of wear. (4) The occurrences are not widespread; although many good sections are obtainable in the Pentland Hills inlier, in only two places are eurypterids found. In both cases the remains are confined to bands a few inches thick, extending laterally but a few feet. (5) The eurypterid fauna appears suddenly with no forerunners and no descendants so far as may be judged from the faunas of the beds immediately below and above the bands containing eurypterids; two of the five genera are confined to this horizon. (The full significance of statements (4) and (5) will be taken up in the next chapter on distribution.)

These are the facts which are generally not mentioned when the eurypterids are declared to be abundantly represented and associated with a good marine fauna. These five facts seem to be difficult of explanation if it be supposed that the eurypterids were marine organisms. How are we to account for the fact that the merostomes accompanied by that form which so often occurs with them, *Dictyocaris ramsayi*, are found in layers separated from those containing the brachiopods, pelecypods, etc.? If the eurypterids lived in the marine waters, why are their remains not found with those of the other marine organisms? Band D contains many genera, species, and individuals of brachiopods, pelecypods, gastropods, cephalopods, crustacea, crinoids, trilobites, corals, the first three groups being especially well represented, the last three by only two or three species. But not a trace of a eurypterid is found in this fauna which, according to the criteria given on p. 76 is a typical marine fauna. Moreover, why should their appearance be so sudden and so localized? The eurypterid band dies out within a few yards of Gutterford Burn, and in the other sections where one would expect to find eurypterids again, for the associated marine fossils occur, there is not even a fragment? I must confess that such anomalies in distribution are not compatible with a marine habitat for the organisms so affected. Again, why should the eurypterids have suffered such maceration, while the remains of the other organisms were entombed in a perfect state? Wonderfully preserved starfishes and trilobites are found in one of the beds, the marvellous brachiopod fauna of Band D has been described and figured by Davidson, and his book amply attests to the abundance and fine preservation of the molluscoidea; but the eurypterids are broken up, often unidentifiable and never what the palaeontologist would consider good material. These questions have been, or will be, fully treated in the appropriate sections on the bionomy and distribution of the eurypterid faunas. We are here concerned only with the lithogenesis of the beds so far as that may be separated from faunal considerations. From the study of the sections, and the lithological characters of the rocks, I offer the following interpretation for the eurypterid-bearing horizons of the Wenlock of southern Scotland.

It will be remembered that the Tarannon marked a period of retreat of the sea toward the south, the shoreline being at the end of that time somewhere in the central part of the Central Belt, while there must have been an embayment in the Girvan area where continuous marine sedimentation was active. The Wenlock sea which covered the greater part of western, central, and northern England at least, advanced over the terrestrial beds which were deposited during Tarannon time. Unfortunately, the most critical areas of deposition of the Wenlock have been removed by subsequent erosion. The Southern Belt was in the region of continuous marine deposition from Tarannon into Wenlock time, as the sections in many places show. Even in the Pentland Hills the base of the Wenlock is nowhere visible, the beds standing on end for the most part and sticking up through the Old Red Sandstone. In Lanarkshire, however, there occurs in the Lesmaghagow inlier only, below the Ludlow, a series of blue greywackes with shale partings which is 1300 feet thick and has proved unfossiliferous throughout except in one locality where a few specimens of Murchisonia (specifically undeterminable) and some doubtful forms called Orthis have been found. It has been thought by the Scottish Survey that part at least of this formation was Wenlock in age. I should like to offer the following purely theoretical suggestion. It has been shown that during Tarannon time rivers flowing from the Eastern Highlands carried down pebbles and boulders which were deposited in the Central Belt. Probably the whole of central and northern Scotland was above water then, and either subaerial erosion or deposition was going on. The 1300 feet of greywackes and shales below the Ludlow in Lanarkshire might represent in their lower part delta or torrential deposits accumulated during Tarannon time and in their later part similar deposits during Wenlock time. Their unfossiliferous character and great thickness would thus be accounted for. Future study in those rocks should be directed towards the search for cross-bedding, if any, and the type represented, for plant remains, tracks, and eurypterids. As the Wenlock sea advanced northwards—there is little reason to doubt that it did, for the same marine fossils are found in the Southern Belt and in the Pentland Hills—it reworked the Tarannon, and a basal sandstone, conglomerate or shale was formed, depending upon the nature of the Tarannon continent where the sea transgressed. Thus along the northern border of the Southern Belt the basal Wenlock consists of "greenish grey, flaggy grits, separated by grey shale bands, some of which are crowded with Crossopodia, Nemertites, and other tracks, resembling those found in the Hawick Rocks." On the Slitrig Water the shales and surfaces of the greywackes are crowded with tracks. These rocks pass conformably downwards into the Tarannon rocks of Hawick, indicating that the actual seashore at the close of Tarannon and beginning of Wenlock time must have been just about in this region. The unfossiliferous grits and greywackes (the first division of the Wenlock) appear along the northern border, while the second division occupies all of the rest of the belt to the south except for small patches or inliers in the extreme south where the third division of the Wenlock is seen; there are also inliers in various localities throughout the belt east of Langholm, showing the basal grits and greywackes projecting up through the second division of the Wenlock. This distribution indicates the presence of the basal sandstone of the advancing sea throughout the southern belt. The single eurypterid fragment found in this belt, it will be recalled, was discovered in the track-crowded shales and greywackes at Slitrig Water. These being interpreted as basal beds of an advancing sea, it is most natural to expect that the sea, rolling landwards and up the rivers, slowly but unceasingly converting the dry land into sea-floor, should catch river-dwellers who were not able to or did not migrate upstream fast enough, and even if there were none such, at least dead remains would inevitably be passed over by the sea in its continued advance. One would undoubtedly expect more than a single fragment and probably more will be found in the southern Wenlock rocks. The more abundant occurrence in the Pentland Hills is explainable on the supposition that the sandy bands containing the broken exoskeletons represent the outwash from rivers into the sea, of shed exoskeletons and maybe even of the remains of eurypterids which were killed off in great numbers by the entrance of salt water into the rivers. So soon as this group of organisms was able to migrate far enough away from the sea which had overtaken the earlier individuals, the appearance of exoskeletons in that region would come to an end, but one would expect similar catastrophes to occur in another locality at a higher horizon. Unfortunately, the exact method of entombment must remain hypothetical, since the exposures are so few, but that the eurypterids did not live in the Wenlock sea is apparent. One further argument which might be adduced is that in the purely marine, open-sea Wenlock of England, not a trace of a eurypterid has been found, although if they were true marine organisms during Lower Siluric time as most geologists claim, then it is surprising that they alone of the marine fauna should be found only in southern Scotland although migration was open along most convenient marine channels into Wales.

8. UPPER SILURIC OF OESEL

For beauty and perfection of preservation no other known eurypterid remains can compare with those from the island of Oesel. Though only five species have been found and only one in abundance, the lack of a varied fauna is entirely compensated for by the rare condition of the fossils. After tens of millions of years the exoskeletons of these organisms now so long extinct appear in the rock, differing not in appearance from the shed skin of a Limulus buried in the sand today. We must be filled with awe and with the profoundest admiration for the marvellous ways of nature, when we look upon these remains unchanged in chemical or physical characters during all the aeons which have passed since they were entombed, still retaining the brown color so familiar in modern horseshoe crabs, with the very chitin of the test unimpaired, while even the brittle exoskeleton itself, at times, can be removed from the rock intact.

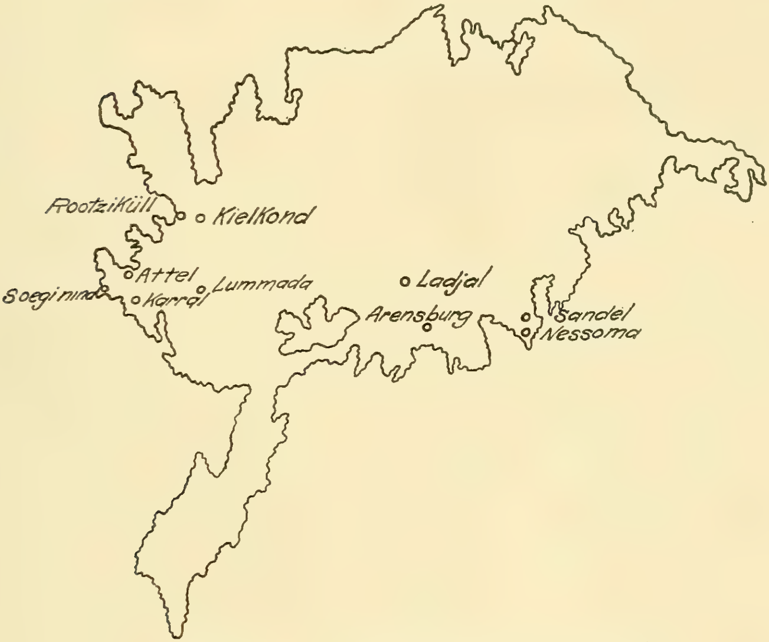

Fig. 13. Sketch Map of Oesel for Upper Siluric Localities

History of Discoveries. This fauna was discovered in 1852 by Dr. Alexander Schrenk, during a trip made for the purpose of studying the Ordovicic and Siluric rocks of the northwest provinces of Russia, namely, Livland and Estland, and of the adjoining islands Oesel, Dago, Moon, Worms, etc. On the first and largest of these islands he found outcrops of the uppermost Siluric rocks in the town of Rootziküll (see map, fig. 13) and there he came upon the first of the eurypterid fauna which was to become world renowned.[9] In his report on this region he says: "The gray, compact dolomite of Rootziküll, on the west coast of Oesel, reveals the thin membraneous tests of *Eurypterus remipes* Dekay [= *E. fischeri* Eichwald] entirely unchanged, not only in their chemical composition, as pure chitin, like that found in the shells of living Crustacea, but also in their whole internal microscopic structure and preserved with their original brown color peculiar to living animals" (Schrenk, **254,** 35).

In the following year, 1853, Eichwald apparently not knowing of Schrenk's discoveries visited the same provinces and islands and on Oesel two versts from Rootziküll in the village of Wita he, too, came upon the eurypterid horizon whose assemblage of organisms surprised him not a little, for he says: "I was astonished to find a vast multitude of *Eurypterus remipes* [*E. fischeri* (Eichwald)] in this limestone" (Eichwald, **57,** 49). By his collections he added much to the knowledge of the rest of the fauna, but I shall not at this point give the species which he found, since later workers added materially to the faunal lists. During that same summer Schmidt and Harder accompanied Eichwald to Wita and other nearby localities where eurypterids were found; in 1856 Schmidt returned again to Oesel and the following year Niezkowski, Schmidt and Czekanowski made large collections at the best localities. Again in 1858 Schmidt revisited the island, and as the result of these extensive collections and field studies several important papers were brought out. By far the most complete and comprehensive were those by Schmidt, the first published in 1858 entitled "Untersuchungen ueber die Silurische Formation von Ehstland, Nord-Livland, and Oesel"[10] embodies the first detailed stratigraphic and palaeontologic discussion of these regions. Schmidt gave the first geologic map of the region and the zonal subdivision of the "Silurian" which is still used in the east Baltic provinces. In the following year Schmidt published a short notice on some further discoveries in Oesel (**243**). His most important paper on this island appeared a number of years later in 1883 as one of the "Miscellania Silurica" in the Memoires de l'Academie Imperiale des Sciences de Saint-Petersbourg, entitled "Die Crustaceenfauna der Eurypterenschichten von Rootziküll auf Oesel." Precise information is given regarding localities, species are fully described and compared with related forms and excellent illustrations are given, so that with these papers and one by Nieszkowski in 1859 on "Der *Eurypterus remipes* aus den obersilurischen Schichten der Insel Oesel" (**197**) one may gain an accurate knowledge of the fauna and the sediments. Notes by Nieszkowski in connection with his work on the trilobites have proved helpful, and for further details the reader is referred to the titles under his name in the bibliography as well as to numerous papers by Schmidt.

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[9] He had been led to look for this fauna because he had noticed in the Dorpat Museum certain fine specimens which had been sent in from Arensburg, southeast Oesel, by Oberlehrer Werner, who had knocked them out of loose blocks of building stone. (Nieszkowski, **197**, p. 303.)

[10] It is true that pioneer work on the mainland had been done by M. v. Engelhardt and E. Ulprecht. the results being embodied in a paper entitled "Umrisz der Felsstructur Ehstlands und Livlands" in Karsten's *Archiv für Min. Geogn. Bergbau u. Hüttenk.* for 1830, but the paper does not touch on Oesel. Similarly in the Geology of Russia by Murchison, de Verneuil and Keyserling Oesel is passed over in a few sentences.

General Stratigraphy. The Siluric exposures on the island of Oesel include two divisions: the lower Oesel group or zone I, and the upper Oesel group or zone K of Schmidt. The strata have a gentle dip to the south so that higher and higher beds appear in that direction. The lower beds, of Wenlock age, cover a considerable part of the northern half of the island, while the upper or Ludlow beds are found in the southern portion (see map, fig. 13). In the extreme north the lowest part of zone I occurs carrying typical Wenlock fossils; southward, as on the peninsula of Taggamois the upper division of the zone is exposed, showing well its dolomitic reef structure; bryozoa, crinoids and brachiopods are abundant, and do not differ essentially from the forms in the underlying marls. The last exposures of the upper part of zone I yield abundant *Thecia swindernana*, a coral found in the Upper Visby beds of Gotland, also *Leperditia baltica*, which occurs in divisions V, VI and VII of North Gotland, *Strophomena imbrex*, found throughout the Wenlock or lower divisions in Gotland, and *Zaphrentis conulus*, characteristic of the upper part of the Visby formation (III) immediately below the Pterygotus marl of Gotland. This higher portion of zone I is to be correlated with the *Leperditia baltica* zone of Gotland (Schmidt, **250**, 132).

Throughout the entire south and southwestern parts of the island, zone I is succeeded by zone K, but the actual contact is nowhere observable. This zone likewise shows two subdivisions, a lower, made up of thin-bedded "plattenkalk" or dolomite, in some places unfossiliferous, in others carrying eurypterids and fishes, and an upper very fossiliferous horizon known as the Ilionia beds on account of the abundance of that pelecypod. The Ilionia beds are to be correlated with zone VI of Gotland which is of Upper Ludlow age. Some of the diagnostic Upper Ludlow fossils recorded from this horizon in Oesel are: *Ilionia prisca*, *Megalomus gotlandicus*, which occurs just above the Ilionia beds in Gotland, *Murchisonia compressa* (Gotland VI), and *Spirigera* (= *Meristina*) *didyma*, which is the most widespread form in the northern outcrops of zone K in Oesel and which occurs at Visby in the top of bed III, in the Sphærocodium marl below the Ilionia limestone, and above the eurypterid marl of Gotland, as well as in the Aymestry limestone and Dayia beds of England, all (except possibly the last two) of Upper Ludlow age. Thus there is evidence of a faunal break in the series, since beds containing Upper Ludlow fossils everywhere in eastwest sections across central Oesel follow upon beds with Wenlock fossils. In many localities the indications of a physical break are also present as may be best shown in a few detailed sections.

The fullest development of the eurypterid fauna is seen in the rocks underlying Rootziküll on the west coast of the island of Oesel in the parish of Kielkond. Here the beds of the lower part of zone K are a fine-grained "plattenkalk" or dolomitic calcilutyte, in which the chitinous exoskeletons of *Eurypterus fischeri* Eichwald, *E. laticeps* Schmidt and *Pterygotus osiliensis* Schmidt have been so excellently preserved. Associated with the eurypterids in the same bed have been found the tail of *Ceratiocaris nötlingi* Schmidt,[11] the shields of two cephalaspid fishes *Thyestes verrucosus* Eichw. and *Tremataspis schrenkii* Schmidt, and the shells of the little *Lingula nana* Eichwald. Nearly fifty years after these first discoveries Schmidt was able to add a new species to the fauna perhaps representing a genus not heretofore known outside of North America. From A. Simonson he obtained a slab which showed the portion of the abdomen and carapace of this new species which he called *Stylonurus* (?) *simonsoni* (252, 157).

Attention has already been called to the fact that the eurypterid exoskeletons have the original chitin still preserved and that this may be lifted from the rock so that both the upper and under surface and the sculpture thereon may be studied. The shells of the remaining fossils which are found in this bed are destroyed; these include the rarely occurring Hemiaspids: *Bunodes lunula* Eichw., *B. rugosus* Nieszk. and *B. schrenckii* Nieszk sp. as well as *Pseudoniscus aculeatus* Nieszk. and the shells of *Orthoceras tenue* Eichw. All of these forms are represented only by carbonaceous films. In the environs of Rootziküll the eurypterid-bearing plattenkalk appears at the surface everywhere and as Schmidt puts it, "In the extent of a single ¼ verst one may here lay out places for eurypterid quarries to one's heart content" (**248,** 29).

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[11] This species was not collected by Schmidt but was described by him from a specimen from Volborth's collections.

Above the plattenkalk horizon is a brecciated limestone of no great thickness consisting of angular or slightly rounded fragments of compact limestone in a matrix of similar limestone which contains *Calamopora polymorpha.* The breccia is not derived from the underlying dolomite, according to Schrenk (**254,** 47). This physical evidence of a break at the top of the eurypterid dolomite has been more fully described from other localities, as, for instance, at Wita, the section next to be considered.

To the southwest of Rootziküll is the village of Wita. Here in the yellowish white dolomite which is the characteristic eurypterid-bearing facies two quarries have been opened. It was found that the eurypterids occurred not only in the dolomite, but also at a higher horizon in a brecciated coral limestone which is made up of angular, sometimes rounded white nodular masses which are for the most part corals lying embedded in a uniform, yellow, marly limestone matrix. Schmidt (**241,** 167, 168) would correlate this bed with the Burgsvick oölite of Gotland, the formation which there marks the break between the upper and lower Gotlandian. The limestone at Wita is only one foot thick; in its upper part it contains *Leperditia baltica*, *Turritella obsoleta* (= *Holopella obsoleta*), *Spirifer elevatus*, and certain corals, all being characteristic of the Upper Ludlow of England and of the Upper Gotlandian of Gotland. In the lower portion of the breccia occur: *Cephalaspis verrucosus*, *C. schrenkii*, *Eurypterus fischeri*, *Bunodes lunula*, a new crustacean *Dithyrocaris* ? sp., *Orthoceras bullatum* ?, *Lingula nana*, and *Palæophycus acicula*, besides many fragments of crustacean claws, segments of walking legs and the like. The section is of importance for three reasons: (1) There is physical evidence of a break at the end of Wenlock or Lower Ludlow time, marking a retreat of the sea. It did not return until Upper Ludlow time as indicated by the presence of fossils of that age in the matrix of the brecciated limestone. (2) The eurypterids occur abundantly in the beds deposited immediately after the normal marine conditions ended, while the sea retreated, and at the time when dry land was being enlarged and consequently rivers were extending their distal portions. (3) The eurypterids are also sparingly found in the breccia and conglomerate which marks the return of the sea and renewed deposition of marine sediments with marine organic remains. (4)

The eurypterids do not occur in the beds with the marine fossils but always in distinct zones a few inches thick, their whole representation being confined to not more than a few feet in the entire Oesel series.

West of Rootziküll a distance of about 5 versts there is an exposure not far from Gesinde Wessiko Maddis along a little brook which rises near Lümmada, but is usually dried up. Here the lower rock is limey, not dolomitic and the eurypterids are not very abundant, but the rock above is crowded with *Platyschisma helicites*, *Leperditia phaseolus*, and the delicate fish scales of *Coelolepis schmidti* Pander together with fragments of seventeen other species of fishes (Schmidt, **241,** 168, **248,** 29). The upper beds are evidently the continuation of the brecciated limestone of Wita. Proceeding in the same southwesterly direction from Rootziküll towards the coast one comes to the Attel estates or Gut Attel where there is a small outcrop of yellow, coralline limestone which on exposure weathers white and which carries *Stromatopora* sp., *Cyathophyllum*, *Favosites hisingeri*, and *F. fibrosa;* similar brecciated inclusions occur as at Wita. A little farther to the west in the village of Attel may be seen on the west side of the deeply indented bay a coarsely crystalline yellow-dolomite and beneath this is the coral limestone of the Attel estates which here is not entirely composed of corals, but contains also *Eurypterus fischeri*, *Lepeditia baltica*, *Orthoceras bullatum*, and *Murchisonia cingulata* = *M. compressa*, the last being the same species which is found in zone VI in Gotland. It is clear that the eurypterid remains at Attel are found not in the plattenkalk beds, which here are barren of all organic remains, but in the overlying coral limestones (Nieszkowski, **197,** 307; Schmidt, **241,** 169, 170). The last section in this series is at the Soegi-ninna point about 12 versts from Rootziküll, where the rock walls rise from the sea to a height of 10 or 12 feet. In the upper part is seen the typical crystalline dolomite with nodular inclusions which here and there give place to thin, unaltered limestone beds with *Leperditia baltica* and *Murchisonia compressa;* the lower part of the rock walls consists of platten dolomites which appear to be the continuation of those of Wita, but which have not yet yielded any eurypterid remains after fifty years of patient search (Schmidt, **151,** 169, 170).

The outcrops in the southeastern portion of Oesel show only traces of eurypterids here and there. For instance, between Uddafer and Ladjal, north of Arensburg, Schmidt found in small ditches along the roadside *Phragmoceras* sp., *Spirigerina prunum*, *S. didyma*, *Pleuro-*

rhynchus sp., *Laceripora cribrosa*, but no eurypterids. In the quarry at Ladjal itself, in a band of limestone apparently in place, there occurred a great mass of *Leperditia baltica*, and also *Spirigerina didyma*, while in marly interbedded layers *Eurypterus fischeri* occurred in traces. To the southeast this limestone merges into solid gray limestones carrying trilobites, crinoids, brachiopods, etc., but not eurypterids. At Nessoma, southeast of Sandel occurs an outcrop of the upper crystalline limestones which marks the *Spirigerina prunum* horizon, and in intercalated brown marly layers were found great numbers of fish scales and breast plates, similar to those occurring at Ohhessare-Pank on the southwestern end of the island. The section at Lode about the same distance west of Arensburg as Nessoma is east of it, has brought to light one of the richest collecting grounds on the island for the typical marine forms. Here the rock is a gray limestone in which *Spirigerina prunum* occurs in great numbers but is not well preserved; *Leperditia baltica* is occasionally found, but the abundant forms are: *Calymene blumenbachii*, *Orthoceras bullatum*, *Spirifer elevatus*, *Orthis orbicularis* and *Chonetes striatella*, all characteristic of the Upper Ludlow of England (Schmidt, **241**, 176–7).

In summary, it may be said that the detailed sections bring out the sporadic occurrence of the eurypterids in very thin beds, rarely intimately associated with the typical marine forms which occur in beds above and below the eurypterid marls. As the beds are traced to the south, southwest and southeast they are seen to be replaced by those containing a pure and abundant marine fauna, but not a trace of a eurypterid. Moreover, it is apparent that the occurrences are in all cases immediately associated with the physical and faunal evidences of a break in the series between beds of Lower and Upper Ludlow age, and that this is essentially the horizon at which the eurypterids and *Palæophonus nuncius* are found on the island of Gotland, marking in both cases what seem to be widespread river deposits which precede the renewed encroachment of the sea in Upper Ludlow time.[12]

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[12] It does not appear to me necessary to take up in detail the discussion of the occurrence of the Pterygotus marl of Gotland, since the conditions there are identical with those of Oesel. The marl overlies beds with a Wenlock fauna, and is succeeded by beds with an Upper Ludlow fauna. The physical evidence of the break between the two series is marked throughout the island. This is fully discussed in a forthcoming paper by Professor Grabau.

9. UPPER SILURIC OF PODOLIA AND GALICIA

Along the Dniester and its tributaries in Galicia and Podolia Upper Siluric rocks have been found containing a few fragments of *Eurypterus fischeri.* This discovery was one of the earliest and was made by Major-Ingenieur Bloede who found a single impression in a piece of shale from an unknown locality in Podolia. Graf Fischer de Waldheim described this form as *Eurypterus tetragonophthalmus*, communicating his description to the Société Impériale des Naturalistes de Moscow in 1839 (**64**). The specific name was given because the eyes were supposed to be of a tetragonal outline, but subsequent study showed that they had the typical margins, and the form was later identified first as *E. remipes*, then as *E. fischeri.* Schmidt records finding the eurypterid remains at the base of the Upper Siluric and notes that just as in the occurrences on Oesel so in Podolia the eurypterids and fish remains are found without any other associates. In regard to the occurrence of *E. fischeri* noted by Barbôt, Malewski, Alth and others, Schmidt makes the following remarks: "In Podolia occurs a species absolutely identical with ours which was formerly identified with *E. remipes*, and which will probably make possible even further differentiation from the American species. So far as I know there have been but three undoubted specimens found up to this time: (1) the original specimen of Fischer (now in Moscow) from Zwilewcy on the Smotricz, (2) Bloede's specimen (in our Bergakademie Museum) from Balagowa on the Dniester, (according to Barbôt); and (3) that from the Kiew Museum obtained from Dumanow. Malewski also cited Zawalje, Kiṭaigorod and Studzienica; but I cannot hold these statements as very reliable, since the specimen from Studzienica which is before me, is the horizontal section of a large *Cornulites serpularius* (Sil. Syst.) which species is well known to me from Oesel (Johannis)" (Schmidt, **245,** 13, 14). The Pterygotus fragments which have been reported, Schmidt considers as identical with *P. osiliensis* (formerly called *P. anglicus*) from Rootziküll. Schmidt continues: "Of the latter I know practically every single piece, but I have never found a complete individual. Also in the transition beds from limestone to sandstone at Zalesczyki I have found broken pieces of shell, which, however, deserve no particular further examination (**245,** 13)." In another place, referring to this last mentioned occurrence he makes the following significant statement: "The uppermost beds at Zalesczyki become sandy and red and the fish alone are present besides the rare Pterygotus" (**245**, 9). (See sketch map, fig. 14.)

While Alth's paper is undoubtedly excellent for the general stratigraphy and palaeontology of Galicia and Podolia, involving as it does not only the results of his own studies but also those of the earlier investigators, it yet fails to give just the details which are essential for the problem in hand. It helps us very little to know that the eurypterids and a large number of the fossils are found in beds some 25–30 feet thick; the important fact is whether or not they occur in thin bands, isolated from the remaining fossils as is the usual way. It must in fairness be stated that Alth's section on the Upper Siluric beds, or as he called them, the "compact and bituminous limestones," does not pretend to be more than a résumé of the important but little known works by Barbôt, de Marny and Malewski, written in Russian, but now made available through this careful German summary. Schmidt's statement has shown that the mode of occurrence above

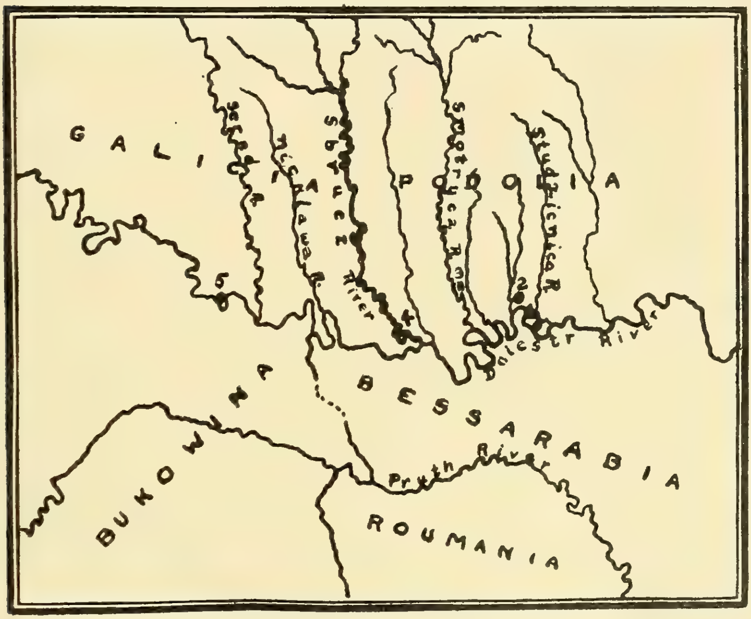

GALICIA
PODOLIA
BESSARABIA
BUKOWINA
ROUMANIA
Sereth R.
Niczlawa R.
Sbrucz River
Smotrycza R.
Studzienica R.
Dniester River
Pruth River
1
2
3
4
5

Fig. 14. Sketch Map of Parts of Galicia and Podolia, Showing Localities where Eurypterids have been Found

1, Studzienica; 2, Kitaigorad; 3, Kameniec podolski; 4, Zawale; 5, Zalesczyki.

referred to as normal holds also in this case for Pterygotus, but there are many other occurrences for which no data are available. However, the rarity and the poorness of preservation of the fragments which have been found make it a matter of no great importance whether the eurypterids are intimately associated with the marine forms or not. I shall here list the localities as given by Alth and other workers in the same field.

Eurypterus fischeri. 1. Eichwald reports this in a black, compact limestone with corals from Kamieniec podolski, Podolia.

2. Malewski reports it from the same limestone at Dumanów, Zawale and Studzienica, Podolia (see Schmidt's remarks above, p. 148).

3. Fragments reported by Wenjukow from Dumanov, Podolia.

4. Siemiradzki reports this species from Zalucze on the Smotrycz river, in a yellow marly limestone (**263**, 215).

Pterygotus osiliensis. Exact locality and horizon not given for Alth's specimens.

Schmidt reports this species from transition beds of Zalesczyki, Galicia.

Siemiradzki has also recorded the finding of fragments which seem to be similar to Alth's undetermined Pterygotus sp. in the olive green shales from the same locality (**263**, 215).

Stylonurus sp. Alth. 1. A tail spine from the plattenkalk of the Borszczower beds from Zamuszyn (Alth Plate V, fig. 4).

2. A tail spine from the light greenish-gray marls into which the gray limestones of the Skalaer group pass upwards, found in the region of the Zbrucz Valley opposite to Zajączki and north of Husiatyn. (Alth Plate V, fig. 5).

3. A tail spine from the thin limestones opposite Zamuszyn (Alth Plate V, fig. 6).

These occurrences in Galicia and Podolia follow the general rule of being very fragmentary and isolated. From the literature one cannot tell whether the eurypterids were actually found in the same beds with the undoubted marine forms or not.

Pterygotus sp. ind. Siemiradzki. Siemiradzki has reported the occurrence of a telson of an undeterminable species of a Pterygotus from the Devonic coral limestone of Skala, Galicia (**263**, 215). This is mentioned here to complete the survey of the Austro-Russian occurrences.

THE LUDLOW OF ENGLAND AND THE LUDLOW AND LANARKIAN OF SCOTLAND

Introduction. Although the Siluric of southern Scotland is characterized by large eurypterid faunas at successive horizons, the rocks of the same age in England and Wales, where more open marine conditions obtained, have yielded only two or three fragments, except in the higher Ludlow beds which mark the transition to the continental deposition characterized by the Old Red Sandstone. Even in the Ludlow the remains which in some strata are abundant show a much poorer preservation than do those from Scotland. Complete individuals are never found and although it is possible from the fragments to determine that different genera are represented, more precise identifications are difficult, and in most cases species have been erected simply in order to have some way of designating the fragments belonging to the various genera. In order to understand why all of the specimens from the Siluric of England are so much more poorly preserved than are those from Scotland, it will be necessary briefly to trace the geological changes which were taking place throughout Great Britain during the later Siluric.

In Scotland the Upper Siluric is marked by the approaching continental conditions as evidenced in the deposits of greywackes and flagstones, some barren, some containing a sparse marine fauna and others only fish and eurypterid remains. The conditions as yet were unstable, showing the alternate dominance now of river-borne sediments and now of shore deposits. To the south, however, the sea still covered most of England, though the muds pouring in from the land had made conditions unfavorable for many of the forms of life which thrived in that region during Wenlock time. Thus the corals no longer built up great reefs and only a few survived in the stifling muds wherein the graptolites were buried in such abundance. Brachiopods and the majority of molluscs likewise decreased in number as the migration to more favorable waters to the south progressed. Toward the top of the Upper Ludlow rock in England many rill and ripple-marked sandstones are to be found, some of which show trails. Near the top of this series too, occurs the "Bone-bed" which varies from $\frac{1}{4}$ inch to 6 inches in thickness and is made up largely of fish, eurypterid and crustacean remains, while a few brachiopod shells have been found in places. Geikie has estimated that this bed probably covers an area of over a thousand square miles and yet it never exceeds and seldom reaches 1 foot in thickness.

Following the Upper Ludlow in England comes a series of formations of no very great thickness which has been subdivided into the Tilestones, Downton Castle sandstones, and Ledbury shales. Murchison applied the name "Tilestones" to the whole of the flaggy upper parts of the Ludlow, and since many of the beds are red he included them in the Old Red Sandstone. They were believed to mark a transition period between the Upper Siluric and the Lower Old Red, but to be more like the latter with which they were therefore classed. The Downton sandstones are a group of red, yellow and gray micaceous rocks from 80 to 100 feet thick, occurring in the neighborhood of Downton Castle, Herefordshire, and also supposed to mark a transition period. They are undoubtedly indicative of the regressive movement of the sea, which began in Lower Ludlow time in Scotland but which was not strongly felt in England till the end of the Upper Ludlow. Then in the Downtonian and other "passage beds" were washed into the deposits, terrestrial and lycopodious, vegetal remains, together with eurypterids, Ceratiocaris and vast numbers of *Beyrichia kloedeni*, together with *Lingula cornea* and *Platyschisma helicites*.

In Scotland all of the beds above the Upper Ludlow are called, by the Geological Survey of Great Britain, the "Downtonian." This series is to be looked upon as "stratigraphical equivalents of the Tilestones, Downton sandstones and Ledbury shales which, in Herefordshire, overlie the Upper Ludlow Rocks and have been classified as forming the highest subdivision of the Upper Silurian rocks" (**215**, 568). It is evident that such a usage of Downtonian will lead to endless confusion, for not a little misunderstanding has already arisen because some authors have placed the English Downton beds in the Lower Old Red, and others have used Downton and Passage Beds almost synonymously. If an attempt is made to use Downtonian in a comprehensive way, coördinate in importance with the terms Wenlock and Ludlow, then difficulties will arise and much circumlocution will be necessary to explain whether the Downton of England or the Downtonian of Scotland is meant and in correlation difficulties will come about because so many different deposits are known by the same name. And especially does it seem inadvisable to adopt a name which in England is used for a subdivision of the Ludlow, and make it in Scotland of the same rank as Ludlow. Therefore, the author most fully agrees with the suggestion made by Goodchild that all of the rocks above the Upper Ludlow in Scotland be hereafter designated by the term *Lanarkian* from the locality in which those higher Siluric beds are so well exposed.

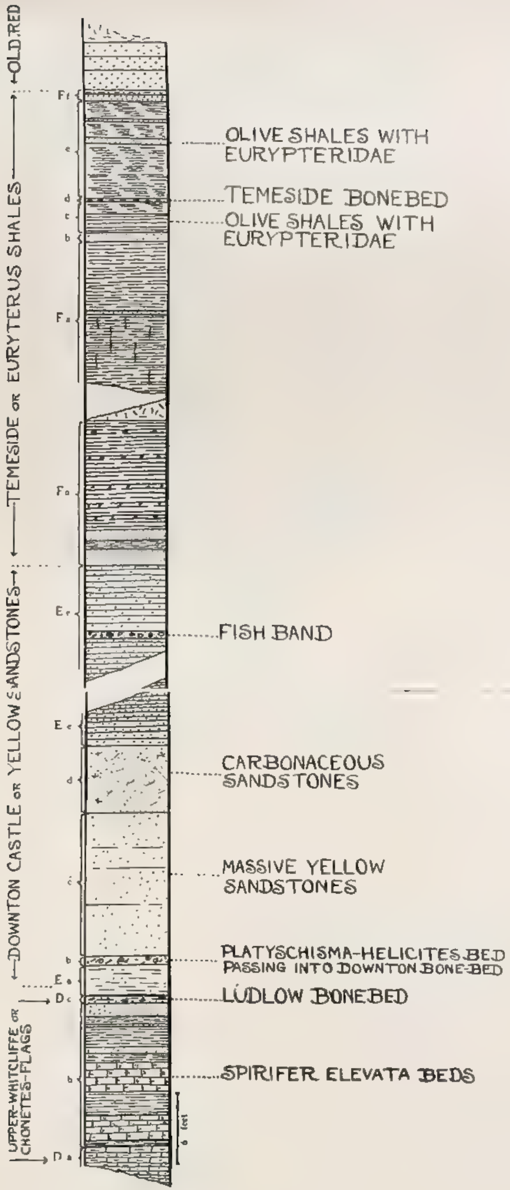
The Lanarkian is a series of conglomerates and sandstones with a total thickness of about 2800 feet, which are either unfossiliferous or contain only fish and eurypterid remains with the usual ostracods, and with Dictyocaris and Ceratiocaris. Plant remains, a myriopod and a scorpion are among the local associates of the above fauna. The series in Scotland is a more strongly marked continental one than that in England. Thus there was a gradual retreat of the sea from the north towards the south, beginning in Scotland in Lower Ludlow time, if not earlier, and leaving all of England except Devonshire dry by the end of the Siluric.

THE UPPER SILURIC OF ENGLAND. It is only the higher divisions of the Ludlow in England which contain eurypterids: i. e., the Upper Ludlow rock, the Ledbury shales, the Downton Castle sandstone, and the Tilestones, according to the commonly accepted classification. Elles and Slater, who have done a great deal of work in the Ludlow district, have been able to determine smaller subdivisions; and since it is from these horizons that the eurypterids have been obtained, I quote so much of the new classification as is needed to follow the merostome occurrences (**61**, 198).

III. Temeside Group	F. Temeside or Eurypterid shales.
	E. Downton Castle or Yellow sandstone.
II. Upper Ludlow Group	D. Upper Whitcliffe or Chonetes flags.
	C. Lower Whitcliffe or Rhynchonella flags.
I. Aymestry Group	B. Mocktree or Dayia shales.
	A. Aymestry or Conchidium limestone.

A few typical sections summarized from those given by Elles and Slater will serve to bring out the relations between the eurypterid-bearing beds, and the strata containing other groups of organisms. On the right bank of the Teme River near Ludlow Castle a section is exposed showing the beds from the Aymestry Limestone through the Downton Castle sandstone. Just a little south of Dinham Bridge which crosses the Teme, less than half a mile west of Ludlow, the Aymestry limestone is seen. This is characterized by *Pentamerus knighti*, *Encrinurus punctatus* and other typical forms. This massive limestone is succeeded by the Mocktree or *Dayia navicula* shales, which in turn are followed by the Lower Whitcliffe flags with abundant *Rhynchonella nucula*, *Orthis lunata* and more rarely *Chonetes striatella*. The latter fossil becomes dominant in the Upper Whitcliffe flags which, together with the succeeding beds, are well exposed in the famous Ludford Lane now known as the Whitcliffe Road section, near Dinham Bridge. *Chonetes striatella* "literally swarms" in these flags, and *Orbiculoidea rugata* and *Orthoceras bullatum* are likewise prolific. It is these flags which show the first traces of fragments of that little known eurypterid, *Pterygotus problematicus*, which occurs in the thin shales and sandstones with *Spirifera elevata*, *Chonetes striatella* and *Orbiculoidea rugata* (see fig. 15). The shales and sandstones carrying the fauna just mentioned, are only four feet thick, yet eight changes in sedimentation are shown, marking a rapid alternation of mud and sand deposition which is clearly indicative of near-shore conditions. Immediately overlying this series is the topmost member of the series, the Ludlow Bone-Bed which though never more than a foot in thickness, is yet one of the most noted of the formations of Britain. It has been the subject of description and speculation for seventy-five years or more; but, so far as I know, its origin has never been satisfactorily accounted for (see proposed explanation below, p. 158). Elles and Wood describe the appearance of the Bone-Bed in this section as follows: "It is best developed at the lower end of the section, on the south side of the road where it is 2½ feet above road-level, and reaches a maximum thickness of nearly 6 inches. It is, however, very commonly separated into two thin bands of 'bony' material, divided by a few inches of soft mudstone. These bands occur in a more or less lenticular manner, and one or the other disappears almost entirely from time to time, even within the short distance occupied by the section (72 yards). This feature is characteristic of all the bone-beds of these highest Silurian rocks. In addition to the numerous fish-remains and crustacean remains which the Bone-Bed contains, we have identified *Chonetes striatella*, *Orbiculoidea rugata*, and *Orthis sp:* a similar fauna, with *Beyrichia* in addition, being found in the softer mudstone separating the 'bony layers.' " (**61,** 203).

Above the Bone-Bed there is a physical and faunal change, the sediments are coarser, sandstones predominating, with only thin interbedded shales, while the genera of brachiopods so characteristic of the strata of the Aymestry and Lower Ludlow have almost vanished



OLD RED
TEMESIDE OR EURYTERUS SHALES
DOWNTON CASTLE OR YELLOW SANDSTONES
UPPER-WHITCLIFFE OR CHONETES-FLAGS
Fc
e
d
c
b
Fa
Fa
Ec
Ec
d
c
b
Ea
Dc
b
Da
6 feet
OLIVE SHALES WITH EURYPTERIDAE
TEMESIDE BONEBED
OLIVE SHALES WITH EURYPTERIDAE
FISH BAND
CARBONACEOUS SANDSTONES
MASSIVE YELLOW SANDSTONES
PLATYSCHISMA-HELICITES BED PASSING INTO DOWNTON BONE-BED
LUDLOW BONEBED
SPIRIFER ELEVATA BEDS

FIG. 15. COMPOSITE COLUMNAR SECTION OF SILURIC OF LUDLOW DISTRICT, ENGLAND
(After Elles and Slater)

with the exception of the Lingulae. Life on the whole became scarce, only the fish, crustacean, and eurypterid remains occurring in any abundance, and these, as is customary, only at certain horizons. The mottled sandstones and shales immediately overlying the Bone-Bed and forming the base of the Downton Castle sandstones is practically barren. Then follows a thin band with Beyrichia which gives place to the Platyschisma bed proper (E b) which is composed almost entirely of *Platyschisma helicites* and *Modiolopsis complanata.* This band is delimited upwards by a second Beyrichia zone. Finally, the massive, yellow, micaceous sandstones of the typical Downton appear (E c). These show leaf-like shale partings with Beyrichia, and other beds with fragments of eurypterids together with the plant (a spore?) *Pachytheca*, and with *Lingula minima.*

The Temeside or Eurypterid shales (F) are not seen in the Ludford Lane section in which even the Downton group is incomplete. It is not possible to find a continuous section at any one place; but the contacts between each pair of the groups have been seen, so that by combining the sections exposed within a distance of about four miles the entire sequence may be obtained. The contact between the Downton Castle sandstones and the Temeside shales may be seen at Forge Bridge, a little over half a mile northeast of Downton Castle; and the junction between the Temeside group and the Old Red sandstone is visible at Tin-Mill Race about half a mile beyond Forge Bridge. The contact of the lowest division of this group (Fa) with the underlying Downton Castle sandstones is not here observable. The first beds are rubbly shales which, a short distance up, contain a band of red shale. At a higher level occurs a local bed containing broken *Lingula cornea*, *Onchus teniustriatus*, Ctenacanthus-like spines and *Leperditia* cf. *marginata* (**61,** 211). There follows a thin sandstone bed, and then a grey shale with *Lingula cornea*, above which comes the typical olive-shale of F d with the Temeside Bone-Bed which is very similar to the Ludlow Bone-Bed. From this horizon Elles and Slater record the following interesting fauna (**61,** 211):

Pterygotus ludensis
P. problematicus
Onchus teniuistriatus
O. murchisoni
O. sp.
Lingula cornea

Ctenacanthus sp. (?)
Cephalaspis sp. (?)
Pachytheca sphaerica

The olive shales above the Bone-Bed also contain many fragments of eurypterids. Evidence of the approach of the Old Red sandstone deposition is seen in the frequent occurrence of grit bands in the olive shales. The top of F f is the "Fragment-Bed" which is crowded with fragments of carbonaceous material whose origin is uncertain, and this layer is everywhere succeeded by the purple-red sandstones of the Old Red.

These sections show the typical lithological and faunal characteristics of the Ludlow in England, and they offer unquestionable evidence for a change from marine to continental conditions of sedimentation. Beginning with the Aymestry group which is a pure marine limestone in the lower part, passing up into shales with thin limestone beds, the succession continues through the flags of the Upper Ludlow group, terminated by the Ludlow Bone-Bed, and finally the Temeside group closes the Siluric. These last beds consist of the Downton Castle sandstones in the lower half, which show an alternation of unfossiliferous sandstones and shales with beds of similar character bearing Lingulas or Platyschisma, or eurypterids or fish remains, while the upper portion constitutes the Temeside or Eurypterus-shales which are dominantly eurypterid-bearing, olive shales, with intercalated grit bands, fish beds and bone-beds. In regard to these formations in the Ludlow-Downton district, Elles and Slater make the following significant statement: "Palæontologically, these rocks are characterized by the presence of Eurypteridae, which, although rare in the lower beds, gradually increase in importance until they attain their maximum development in the beds immediately underlying the Old Red sandstone. The rich brachiopod-fauna, characteristic of the lower beds, dwindles and almost dies out with the approach of shallow-water conditions, although the molluscs are somewhat more persistent" (**37**, 197). The eurypyterids occur in thin seams not associated with the fast diminishing marine fauna, but with crustacea such as Beyrichia, with the thin-shelled *Platyschisma helicites* and occasional Lingulas, and especially with fishes. The eurypterids are scarce in the Aymestry and Upper Ludlow groups, but become abundant in certain layers in the Temeside group where they are found in cross-bedded sandstones, in bone-beds, and characteristically, in olive-colored shales.

The physical and faunal characteristics which have just been described have usually been interpreted as indicative of shallow-water marine conditions of sedimentation during the late Siluric. The physical nature of the Temeside group would, perhaps, not preclude such an origin, but the faunal characters leave no doubt that the Temeside group must have been deposited on the land. As is so frequently the case in such successions of sands and flags, there is no doubt that the material is terrigenous in origin, the only question being the place of deposition, whether on the land or along the littoral margin of the sea. If we apply the criteria for the recognition of the various types of fossil faunas, it is at once evident that neither throughout the Temeside group nor at any particular horizon in it is there a marine fauna, for we have seen that a marine fauna, whether existing under the rather uniform conditions of the open sea or under the more variable environment of the littoral zone, and whether in a sandy, muddy, or pure water facies, was yet made up of diverse classes of organisms with a scattering representation through the phyla of the Invertebrata. In the Temeside group there is no bed containing representatives of more than two invertebrate phyla and usually only one phylum is represented. The maximum thickness of this group is 170 feet. In the lower 50 feet (Downton Castle sandstones) the deposits are cross-bedded and contain *Lingula minima* at certain levels, but no other fossils. Such a series is to be accounted for only by deposition at the mouth of a river, either on the subaërial portion of a delta or on the flood-plain, but the coarseness of the deposits implies that the former was the more probable region of deposition. The presence of beds of Lingulae is easily accounted for by the nature of the shells which are thin, corneous, and consequently of small specific gravity. Exceptionally high tides would easily wash in such light shells far up over the delta, while heavier shells would be dropped farther out in the littoral waters. It is evident that the Lingulae must have been transported from their original habitat since they are unassociated with any other forms of life, unless they can be regarded as living in the river mouths. Thus the assortment seems to have been by specific gravity. In the 120 feet of the Temeside group, *Lingula cornea* replaces *L. minima* in the single bands, and is to be accounted for in a similar manner. Now it might be suggested that the eurypterids, which are likewise found in thin bands, were also washed in from the sea on account of their light specific gravity; but the difference between the two cases is that the Lingulae are found in abundance in the marine littoral fauna where they occur, normally associated with marine species of molluscs, crustacea, etc., in the marine deposits of the same age further south; furthermore, Lingulae are found from the Cambric to the present in undoubted marine associations. The eurypterids, on the other hand, are not found in the unequivocal marine deposits to the south, but appear quite as suddenly as the Lingulae, although in separate bands. They have been found to the north of the Ludlow area in Scotland, always as concomitants of the transition from marine to continental conditions, and it is only when the latter conditions transgress farther and farther south that the eurypterids appear.

I think that much light will be thrown upon the interpretation of the late Siluric deposits in England by the study of the Ludlow and higher bone-beds. It will not be possible in this paper to consider the habitat of the early fishes except incidentally, but if that is proved to be fluviatile, as I think it may be, then the following explanation may be offered for the bone-beds. The Ludlow Bone-Bed, which is the most constant and widespread, appears to mark the wholesale destruction of the fishes in the rivers at the time when, in the oscillatory movements preceding and accompanying the retreat of the sea, there were temporary advances. The salt water, pushing its way up the rivers, killed the fishes and other river organisms in great numbers, for the fluviatile fishes can less easily survive an influx of salt water than marine fishes can an influx of fresh water. This is implied in Günther's statement that "On the whole, instances of marine fishes voluntarily entering brackish or fresh water are very numerous, whilst fresh-water fishes proper but rarely descend into salt water" (**97**, 187). Thus during the oscillations preceding a negative eustatic movement, the sea would occasionally advance a short distance over the land, and if this temporary positive movement were widespread, bone-beds would be formed at or near the mouths of many rivers almost contemporaneously, and even if some areas were submerged and others not, geologically the bone-beds would appear to be approximately synchronous. This theory is borne out by the occurrence of thin bone-beds at a number of higher levels in the beds above the Ludlow Bone-Bed. Moreover, whenever there was a slight retreat of the sea with the pushing forward of terrigenous, coarse material, then the light Lingula shells might well be left stranded along the line marking the high-water level for that particular period. If such a negative movement were followed by a slight positive one, with the consequent killing off of the fish, a bone-bed would be formed and in a given section would be found overlying a Lingula bed, as does the Temeside Bone-Bed (F d). Were the sea to retreat again, more Lingulae would be left stranded, while fluviatile organisms that were light enough might be floated out across the flood-plains of the rivers. These flood plains had but just been retrieved from the sea and would have been so slightly raised above sea level that only lighter organic remains such as the Lingulae were washed over it, thus fluviatile remains of small specific gravity would be carried out across the flood-plain there to come to rest with the Lingulae, and in this way the olive shales with eurypterid fragments and *Lingula cornea* would be easily explained. The impossibility of considering either fish or eurypterids as washed in from the sea is indicated by the absence of these forms in the open marine waters to the south. While I have made no attempt to prove the fluviatile habitat of the fishes, yet the bone-beds seem capable of explanation on no other hypothesis. Sometimes the beds are only $\frac{1}{4}$ inch thick, containing no complete remains but only a great mass of broken bones, spines, and scales. Such an accumulation could be formed only of transported material, the fish skeletons having been entirely scattered. If a bone-bed were accounted for as due to the sudden destruction of fishes in the sea by a current of colder or more saline water, by an earthquake or some other catastrophic calamity, then the fish would die in great numbers, but their remains would be buried in situ. An illustration of this is found in the case of the tile fish off the New England coast, where, in 1882, according to estimates, over one billion fish were destroyed, and the ocean floor was covered in this region to a depth of 6 feet with the bodies of the dead tile fish (Grabau, **87**, 195). Entire skeletons would be preserved in the rapid burial, and other marine organisms which suffered the same fate as the fish would also be entombed, so that the resulting deposit would in no way resemble the bone-beds, which are made up of fragments, usually so broken that identification cannot be made, while marine shells are only rarely found.

THE LUDLOW AND LANARKIAN OF LANARKSHIRE. The inliers of Siluric rocks are larger in Lanarkshire than in the Pentland Hills, and the succession is shown more completely, for in Lanarkshire the structure is anticlinal, while in the Pentland Hills the beds have been repeatedly faulted and stand nearly vertical, making it impossible to trace an outcrop except along the strike. About 5500 feet of Siluric strata are exposed, ranging in age from questionable Wenlock, through the Ludlow and Lanarkian (Downtonian) and into the volcanic series of the Lower Old Red sandstone. The eurypterids are found in many more localities than in the Pentland Hills, but they are never so abundant nor are so many genera and species represented. There are four important Siluric areas in Lanarkshire, but in only two of these have eurypterids been found, namely in (1) the Lesmahagow inlier, and (2) the anticline of the Hagshaw Hills.

(1) *The Lesmahagow Inlier.* This is the larger of the two anticlines and extends from a little north of Muirkirk northeast for 6 miles. The Greenock Water in the southwest and the Logan Water in the northeast have exposed a number of excellent sections in the gently dipping beds. The lowest beds exposed consist of a series of blue greywackes with shale partings, the whole comprising 1300 feet as seen along the southern margin of the area along the headwaters of the Ponesk and Nethan. Only a few specifically unidentifiable fossils have been obtained from this series which is provisionally placed with the Wenlock. Immediately to the north of these beds occur grey, blue and olive shales, with occasional nodular greywacke bands yielding a good representation of lowest Ludlow fossils.

The third subdivision recognized by Peach and Horne constitutes the so-called Ceratiocaris beds which are of particular significance because of the surprising abundance in some places of several species of Ceratiocaris, and because of the occurrence of the Ludlow fish, *Thelodus scoticus* in one layer and finally because of the association of eurypterid remains with both of these. At many different points along the Logan Water the beds are excellently shown. In a small gorge about three-quarters of a mile to the northeast of Logan House the lowest of the Ceratiocaris beds dipping to the northwest are succeeded by some zones of dark, fissile calcareous flaggy shales which weather a rusty brown and which have yielded the following fossils:

Worm tracks
Ceratiocaris laxa Woodw. and Jones
Ceratiocaris longa Woodw. and Jones
Ceratiocaris papilio Salter
Ceratiocaris stygius Salter
Ceratiocaris telson, like *murchisoni* M'Coy
Slimonia acuminata Salter

In the same shale band about a half a mile distant the following fossils were found, the eurypterids occurring in great abundance, but the Ludlow fish *Thelodus scoticus* being represented by only two fragments (**215**, 573):

Myriopoda ? (impressions of)
Ceratiocaris sp.
Dictyocaris ramsayi Salter
Pterygotus bilobus Salter
Slimonia acuminata Salter
Thelodus scoticus Traq.

In certain members of the Ceratiocaris group, though a little below the fish horizon, there are recorded from Long Burn, a tributary of Logan Water, the following species:

Modiolopsis nilssoni (His.)
Spirorbis sp.
Beyrichia kloedeni (M'Coy)
Beyrichia kloedeni var. *torosa* (Jones)
Lingula minima (Sow.)
Orthonota sp.
Ceratiocaris
Dictyocaris ramsayi (Salt.)
Pterygotus bilobus (Salt.)
Platyschisma (*Trochus*) *helicites* (Sow.)

The best development of the Ludlow fish band occurs about ½ mile south of Logan House in which place also was found an excellently preserved scorpion *Palaeophonus caledonicus*. In the same place in a cliff about 30 feet high a good section is exposed, showing hard greywacke bands at the top, but below these are brown flaggy shales containing Ceratiocaris in abundance and a few Pterygotus fragments. Embedded in these shales are ironstone nodules which contain fish remains. From this outcrop the following fossils have been collected (**215**, 574):

Archidesmus loganensis Peach
Ceratiocaris longa Jones and Woodw.
Ceratiocaris murchisoni ? M'Coy
Ceratiocaris papilio Salter
Ceratiocaris stygius Salter

Slimonia acuminata Salter
Physocaris sp.
Pterinea retroflexa Wahl.
Platyschisma (*Trochus*) *helicites* Sow.
Thelodus scoticus Traq.
Thelodus planus Traq.
Fish fragment undetermined

Overlying the Ceratiocaris beds and appearing as a narrow band to the north of them throughout the area is a series of hard blue and grey flaggy shales and mudstone, with occasional calcareous nodules. These constitute the Pterygotus beds, 350 feet thick, and are the ones from which Dr. Slimon of Lesmahagow made his extensive collections. The best section is along the Logan Water which for quite a distance runs along the strike of the beds. On the right bank about 400 yards west of Dunside the following fossils have been collected (**215**, 575):

Ceratiocaris papilio (Salt.)
Neolimulus falcata (Woodw.)
Eurypterus lanceolatus (Salt.)
Eurypterus obesus (Woodw.)
Eurypterus scorpioides (Woodw.)
Pterygotus bilobus (Salt.)
Pterygotus bilobus var. *acidens* (Woodw.)
Pterygotus bilobus var. *inornatus* (Woodw.)
Pterygotus raniceps (Woodw.)
Slimonia acuminata (Salt.)
Stylonurus logani (Woodw.)
Lingula minima (Sow.)

"In a small tributary of the Logan Water from the north, at a spot about 250 yards west from Dunside, these flaggy shales have yielded specimens of *Spirorbis lewisi*, *Beyrichia kloedeni*, *Dictyocaris slimoni*, *Pterygotus bilobus*, *Slimonia acuminata* and *Platyschisma helicites*."

In several others of the tributary burns the eurypterids are found associated always with Ceratiocaris or Dictyocaris, *Beyrichia kloedeni* usually and sometimes lingulas.

Still higher horizons of the Ludlow, numbers 5 and 6 of Peach and Horne's subdivisions have yielded eurypterid remains in the basin of the Greenock Water. From the sand greywackes and greenish shales E. N. E. of Waterhead the following fossils are recorded (**215**, 576):

Slimonia acuminata (Salt.)
Beyrichia kloedeni (M'Coy)
Dictyocaris sp.
Spirorbis lewisi (Sow.)
Goniophora cymbaeformis (Sow.)
Modiolopsis complanata (Sow.)
M. nilssoni (His.)
Orthonota impressa (Sow.)
O. rotundata (Sow.)
O. solenoides (Sow.)
Platyschisma helicites (Sow.)

Following upon the highest of the Ludlow green flaggy and sandy greywackes there is in many localities a conglomerate of varying thickness conformable, so it is stated, upon the Ludlow. In the Lesmahagow inlier, however, this conglomerate is absent. On the northwest slope of the anticline the transition beds are exposed in many places showing the change from greywackes to cross-bedded red and yellow sandstones, 1300 feet thick, and constituting subdivision 8. Overlying this is a group of strata, about 100 feet in thickness, containing the very important fish-band. Sections along the Dippal Burn and various streamlets emptying into the Glengarel and Kype Waters show the succession. The fish-band itself is only from 12 to 15 feet thick, comprising an alternating series of brown flaggy carbonaceous shales and green mudstones. It is in the former that the fishes and eurypterids occur, but no organic remains have been found in the mudstones. There are many sections from which the fish and eurypterids have been obtained, but two will suffice to show the nature of the fauna. Near the head of Dippal Burn there have been obtained (**215**, 578):

Eurypterus dolichoschelus (Laurie)
Ceratiocaris sp.
Lanarkia spinulosa (Traq.)
L. horrida (Traq.)
L. spinosa (Traq.)
Thelodus scoticus (Traq.)
Birkenia elegans (Traq.)

Pachytheca
Parka n. sp.
Fucoid-like markings

One of the two best localities for ichthyolites and the one in which all of the species of Downtonian fish determined by Dr. Traquair have been found is in the Slot Burn, one of the tributaries of the Greenock Water. The fossils thus far described from there are (**215**, 578):

Eurypterus dolichoschelus (Laurie)
Stylonurus ornatus (Laurie)
Myriopod
Lanarkia spinulosa (Traq.)
L. horrida (Traq.)
L. spinosa (Traq.)
Thelodus scoticus (Traq.)
Birkenia elegans (Traq.)
Lasanius problematicus (Traq.)
Ateleaspis tessellata (Traq.)
Ceratiocaris laxa (Jones & Woodw.)
Dictyocaris sp.
Pachytheca sp.
Plant stems.
Sponge?

A second fish band yielding several species of fishes and a myriopod has been found a short distance up the Slot Burn and at a slightly higher horizon than the main one; eurypterids have not yet been found in it.

An excellent section in the eastern area of the Lesmahagow anticline is shown in the Birkenhead Burn, a tributary of the Logan Water. The passage from the Ludlow to the Downtonian is obscured by a normal fault which abruptly truncates the Ludlow series, but the rest of the succession is complete. The total thickness of the fish-band with the intercalated mudstones is here fifteen feet. The lowest fossiliferous carbonaceous seam is about a foot thick, while higher up in the band the seams vary from one to six inches. "The remarkable feature of this exposure is the constant association of the fish fauna with eurypterids that are characteristic of the underlying Upper Ludlow rocks." The fossils listed are (**215**, 580):

Eurypterus sp.
Pterygotus bilobus ? (Salt.)
Lanarkia horrida (Traq.)
L. spinosa (Traq.)
L. spinulosa (Traq.)
Slimonia acuminata (Salt.)
Stylonurus sp.
Thelodus scoticus Traq.
Ateleaspis tessellata (Traq.)
Ceratiocaris sp.
Birkenia elegans (Traq.)
Lasanius problematicus (Traq.)
Plants
Sponge

2. *The Anticline of the Hagshaw Hills.* About five miles to the south of the Lesmahagow anticline rises the crest of the Hagshaw Hills anticline, the axis trending northeast southwest. The area between the two anticlines is occupied by a northern belt of limestone, Mississippic in age (Calciferous limestone of Scottish geologists), and by a southern area of Lower Old Red sandstone with one patch of Upper Old Red. Rising above these is the anticline forming the Hagshaw Hills, where the Wenlock, Ludlow and Downtonian are exposed by erosion. It is only in the northern limb of the anticline that the Wenlock and Ludlow are visible, for the southern has been cut off by a thrust fault along the plane of which the older Siluric rocks have been brought to rest against the younger ones. The Douglas Water and its many small tributaries have exposed a number of good sections in the western area of the anticline. One of the best of these is in the Ree Burn, south of the Glenbuck Reservoir where there is an almost continuous section of the Ludlow rocks. At one point in certain blue finely bedded shales and flaggy greywackes specimens of Ceratiocaris, Slimonia and *Beyrichia kloedeni*, have been found. Along the southeastern slope of the anticline where the Podowrin Burn joins the Douglas Water near Monksfoot a transverse section of the Ludlow rocks is shown. They are greywackes and flaggy shales and are thought to be the equivalent of the lowest Ludlow in the Lesmahagow area. It has not been possible to obtain any definite statement as to the exact horizons in which the fossils occur and whether the eurypterids occur as they

do elsewhere in bands distinct from the layers containing molluscs, brachiopods, etc. From this locality the Ludlow beds have yielded the following fossils (**215,** 583):

Slimonia acuminata (Salt.)
Beyrichia kloedeni (M'Coy)
Ceratiocaris papilio (Salt.)
Favosites asper (D'Orb.)
Lindströmia sp.
Glyptocrinus basalis (M'Coy)
Crinoid stems
Ceriopora sp.
Strophomena (*Leptaena*) *rhomboidalis* (Wilck.)
Ctenodonta sp.
Cornulites sp.
Calymene blumenbachii (Brong.)
Encrinurus sp.
Illaenus sp.
Proetus stokesi (Murch.)
Athyris (*Glassia*) *compressa* (Sow.)
Orthis bouchardi (Dav.)
O. (*Dalmanella*) *elegantula* (Dalm.)
O. polygramma (Sow.)
Orthonota sp.
Orthoceras angulatum (Wahl.)
O. small smooth sp.

Along the Smithy Burn, the West branch of the Podowrin Burn, Mr. Tait found a brown sandy shale which because of the abundance of the Bryozoan Glauconome has been called the Glauconome band. This immediately overlies the fish beds and contains (**215,** 585):

Eurypterus dolichoschelus (Laurie)
Glauconome disticha (Goldf.)
Lasanius problematicus (Traq.)
Ateleaspis tessellata (Traq.)
Spirorbis sp.
Sponge
Pachytheca sp.

The Lanarkian series is typically developed along the northern limb of the anticline from the local conglomerate at the base found only in the Hagshaw Hills to the chocolate-colored sandstones at the top, but the only bed of particular interest in the present discussion is the fish band which has been found in several places. In the Monk's Water, about three-quarters of a mile south of Monkshead, the following fossils are reported from this band:

Eurypterus, small sp.
Scorpion
Ceratiocaris ?
Thelodus scoticus (Traq.)
Birkenia elegans (Traq.)
Lanarkia spinosa (Traq.)
L. spinulosa (Traq.)
L. horrida (Traq.)
Lasanius problematicus (Traq.)
Sponge?

II. THE OLD RED SANDSTONE

HISTORY AND SUBDIVISION. The closing stages of the Siluric in northwestern Europe were marked by an expansion of the continental areas and an accompanying widespread retreat of the sea which left all of Great Britain except the southwestern portion of Devonshire, all of Scandinavia, Finland, and the northern borders of Germany dry land. Over the region thus exposed was deposited a great series of conglomerates, sandstones, and shales, dominantly red in color, and reaching a thickness of many thousands of feet, the formations being collectively called the Old Red sandstone facies of the Devonic. It was early recognized that the conditions of sedimentation under which these deposits accumulated were essentially different from those under which the marine Devonic limestones of Russia, western Europe, and extreme southwest England were formed. Not only did the tremendous thickness of the beds attract attention, but the coarseness and prevailing red color of the deposits, and particularly the almost entire absence of organic remains, caused considerable speculation on the part of continental as well as British geologists on the origin of this remarkable series. In the early part of the last century the suggestion was made by Dr. John Fleming that the Old Red might have been deposited in lakes. This theory was eagerly taken up first by Godwin-Austen (6) in 1855 and by a host of later writers, each one of whom contributed some bit of evidence, be it palæontological, geographical or stratigraphical, to show that these Devonic red beds were laid down in lakes. The attempt to prove this theory has, as is so often the case in the development of science, led to careful observations by many men, to the formulation of alternative theories and to the collection of a great mass of valuable data. That the first theory may perhaps prove incorrect is of small importance compared to the fact that it made geologists realize that there was a problem to be solved, and spurred them on to its solution. This lacustrine theory, however, has had a longer life than is usually allotted to first theories, for it has held on to the present day and still has more adherents than has any later hypothesis. The monograph by Sir Archibald Geikie "On the Old Red Sandstone of Western Europe," published in 1878, embodied such an elaborate discussion of the various lakes of the Devonic period and so many field observations were adduced to back up the theoretical statements that later writers have with few exceptions considered that the lacustrine origin for the Old Red sandstone was proved beyond any further question. To be sure, one or two heretical geologists have raised objections to these ancient lakes and have preferred to think that the Old Red was a marine deposit formed under particular and inimical conditions. Within the last ten years both of these interpretations have been questioned by not a few, and although the majority of geologists unhesitatingly accept the older ideas, particularly favoring the lacustrine theory, nevertheless, there is an ever-increasing tendency at the present time to recognize the fact that all continental formations need not necessarily be deposited in large bodies of standing water. Thus the ultra-modern school of geologists champions the importance of fluviatile deposits in the past, insisting especially upon the fact that such deposits are spread out in large part on the land and not in lakes or inland seas. This school of "terrestrial" as opposed to "aqueous" geologists, found its earliest leaders in Johannes Walther and Albrecht Penck, later disciples in this country being Professors Grabau and Barrell. The last two as well as Walther and Goodchild have argued the dominantly continental origin of the Old Red sandstone, Professor Grabau arguing on the basis of the field evidence and on lithological and palaeontological grounds; and Professor Barrell from the standpoint of the physical conditions which must have prevailed at that time. These various theories will presently be taken up and the evidence for each will be discussed.

The present outcrops of the Old Red sandstone in the British Isles are for the most part discontinuous and decidedly patchy. They fall roughly into five areas (see index map, fig. 16): (1) The Caithness-Orkney Islands region with a northward continuation into the Shetlands and a southward one into Sutherland and Rosshire, including the coastal strips on both sides of the Moray Firth; (2) The Forfar-

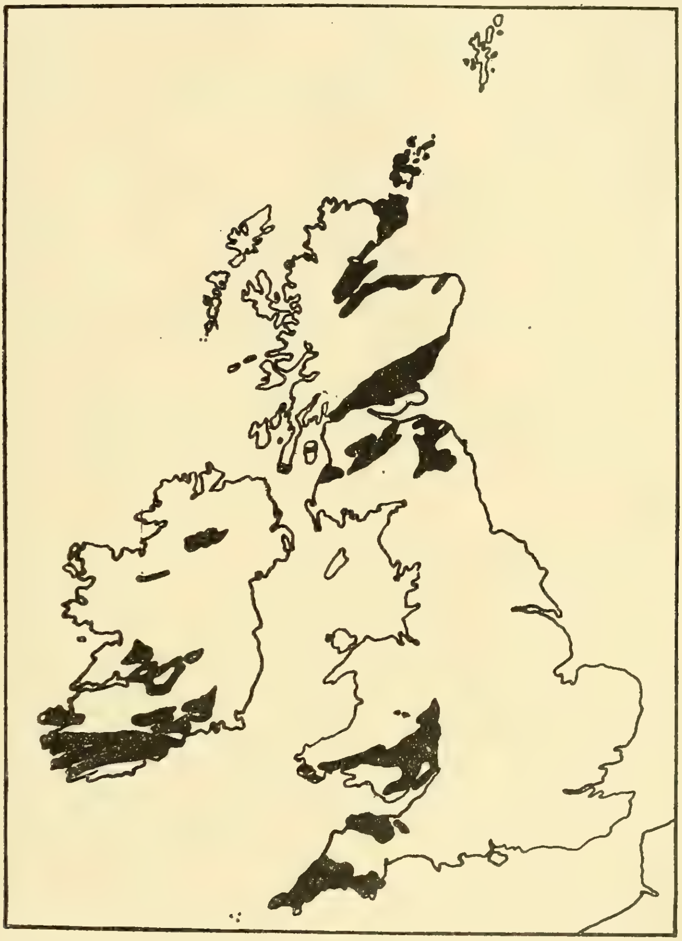


FIG. 16. SKETCH MAP OF BRITISH ISLES SHOWING DISTRIBUTION OF THE OLD RED SANDSTONE
(After Lake and Rastall)

shire-Kincardine and Perthshire area, with discontinuous outcrops in northern Argylshire, together with patches along the Caledonian Canal; (3) Scattered outcrops in southeast Scotland and the Cheviot Hills; (4) The southwestern and southern district of Wales; (5) western England together with the southern and southwestern portions of Ireland. The lack of geological and geographical continuity in these sections, the distinctness of the faunas where present, and the complicated tectonic relations, have led to many different classifications which have been made to fit not only the facts observed in the field, but also the hypotheses evolved to account for the facts. Moreover, since the deposits have not been formed in the sea, as I shall demonstrate below, none of the usual criteria for correlation of marine strata are available, and thus in each locality where the formations are described local names are given to the beds and it is impossible to state what are the equivalents elsewhere. The same lithological facies are repeated again and again, there being rapid vertical and lateral changes, but nowhere is the succession twice alike.

The original subdivision of the Old Red sandstone was made by Murchison before the middle of the last century into three groups, as follows:

Upper Old Red or Dura Den beds,
Middle Old Red or Caithness flags,
Lower Old Red or Arbroath flags.

The lower series is typically developed in Forfarshire, where it consists of coarse conglomerates for the most part, though shales and sandstone are also represented. The middle series is the remarkable grey, flaggy facies exhibited in Caithness and carrying the abundant fish fauna, while the upper is a yellow sandstone group found overlying the flags at Dura Den. Murchison's chief reason for making the Lower and Middle separate, even though the two are never found in contact or even in the same locality, was the distinctness of the faunas in the two, for while the fish and eurypterids of the Arbroath flags were generically and sometimes specifically like those in the Upper Siluric, they were entirely different from those in the Caithness flags, a statement which later investigators have strengthened. Geikie, however, contended that the Lower and Middle were synchonous deposits in separate lakes and that the faunas were not entirely distinct, and even today Geikie supports the two-fold division making the Lower include the Arbroath flags and the Caithness flags, while in the Upper are the Dura Den beds, which for the most part rest unconformably upon the Lower Old Red or transgressively on older rocks (Geikie, **74,** 1006).

Dr. Goodchild, who has worked over the Scottish rocks for nearly fifty years, has taken exception to a number of the prevailing ideas about the Old Red and has given a new subdivision. He has returned to a threefold subdivision for these rocks as they occur in Scotland, the divisions corresponding in many respects to those made by Murchison, although he does not use the terms Lower and Middle because they have been employed with such different meanings by various writers that he deems it best to use locality terms. Thus he gives the following subdivisions of the Old Red sandstone in Scotland, the Orcadian succession being based on Traquair's work (**272–275**) on the ichthyology and on Flett's studies (**66**) in the Orkneys (**80,** 600).

Upper Old Red Sandstone:

2. Higher subdivision, or Elgin beds (now known to be Triassic).
1. Lower subdivisions, or Nairn beds. 0–1,000′
   (Extensive unconformity).

Orcadian Old Red:

5. John o'Groats Flags.
4. Thurso or Rousay Beds.
3. Achanarras, Stromness, and Cromarty Beds.
2. Berriedale sandstones.
1. Badbea Breccias and Basal Conglomerate. 0–16,000′

Caledonian Old Red Sandstone:

3. Strathmore sandstones (the upper part of which may be contemporaneous with the lowest part of the Orcadian).
2. { Myriopod Beds.
   Volcanic Rocks.
   Acanthodian Beds of Turin Hill.
   Cephalaspis Beds of Auchtertyre.
   Volcanic Rocks.
   Pterygotus Beds of Carmylie, etc.
   Tealing Beds.
1. Lower Series of sandstones, mudstones, conglomerates, etc., base not seen. Ranging to ? 20,000′

(Extensive unconformity).

The Lanarkian Rocks (Downtonians of the Geological Survey, the original Lower Old Red of earlier writers).

Ludlow Rocks.

Mr. George Hickling who has made a special study of the Lower Old Red in Forfarshire, where it is typically developed, has given a somewhat different tabulation (**117**, 398):

	Feet
Edzell shales	1,000
Arbroath sandstone	1,200
Auchmithie conglomerate	800
Red Head series	1,500
Cairnconnon series	2,000
Carmyllie series	1,000
Dunnottar conglomerate	5,000
	12,500

The employment of different names for deposits perhaps synchronous, but occurring in different localities, is inevitable because of the lack of stratigraphical continuity and because the fossils which are found in these rocks are not of the type to serve as good index fossils, if, as I hope to show, they lived in the rivers.

It will not be possible to work out the lithogenesis of the eurypterid-bearing beds in the Old Red by a study of those beds alone; rather must we take a broader view that will lead to an interpretation of the climatic and other physical conditions which obtained throughout the Devonic in the regions where red sedimentation was going on. Having determined what these conditions were, the origin of the sediments, the agents of transportation and especially the nature of the areas in which deposition occurred, i.e. whether under water or on the land, then the character of the faunas and of the restricted beds in which they occur, will automatically be ascertained. A few detailed sections in the type localities will enable us to generalize later on.

The Caledonian. At the end of the Siluric there was a period of folding and erosion, the extent of which is not known, but most of the sections indicate that it was long, and perhaps nowhere has a true gradational contact been found between the uppermost Siluric and the lower Old Red. Goodchild remarks in this connection, "So far from graduating downward into the Silurian rocks, the local base of the formations under notice (the Caledonian) lies with a violent unconformity upon all of these rocks, and may repose indifferently upon Silurian, Ordovician or even older strata, including the metamorphic rocks of the Southern Highlands of Scotland. What has been taken as the Caledonian Old Red in the cases where it has been supposed that a passage exists is in reality a series of quite different age" (Goodchild, **80,** 598, 599). As further evidence of the great break between the two systems Goodchild adds that the Lanarkian rocks shared in all of the tremendous disturbances to which the Siluric rocks were subjected and that "these disturbances had ceased, and had been followed by prolonged denudation, long before the oldest member of the Caledonian Old Red was laid down. Hence it results that the great unconformity, so often referred to, passes above what is left of the Lanarkian rocks. There is no clear evidence of any unconformity below them" (Goodchild, **80,** 599).

Thus from the many sections described in the Scottish literature and especially from the authoritative statement of Goodchild, there seems to be good reason for believing that there was a great unconformity at the end of the Siluric, caused in part by profound tectonic disturbances, and that following upon these there was a long period of erosion before the earliest of the Caledonian deposits were laid down. These were of great thickness, amounting in some places to 20,000 feet. As to the origin of the series Goodchild says: "There appears to be evidence of a satisfactory nature that the whole of the vast formation was accumulated under continental conditions, partly in large inland lakes, partly as torrential deposits of various kinds, partly as old desert sands, and partly as the results of extensive volcanic action" (**80,** 596).

A brief review of the lithological characters and distribution of the Caledonian Old Red series will show most clearly that the rocks throughout are of continental origin. The lowest member, division 1, consisting of sandstones and conglomerates, is often wanting altogether, the overlying volcanics being the first of the series to be present. At the Falls of Clyde, near Lanark, Lanarkshire, these lower beds are, however, to be seen, and they are also found in a few other localities. Generally, the volcanics rest immediately and with a violent unconformity upon various pre-Devonic formations. It is these lavas which are seen in the Ochils and Sidlaw Hills, in the Pentlands and in the vicinity of Oban, at St. Abb's Head and also in the Cheviot Hills. In their greatest development in the Perth and Forfar Hills the volcanics may well reach several thousand feet in thickness, but they thin away toward the north and northeast and pass into alternating sedimentary and igneous rocks which were contemporaneous in their development with the main volcanic outpourings (see sketch map, fig. 17).

The first important fossiliferous beds are those found at Carmylie and adjoining localities in Forfar. These constitute a part of the famous Arbroath flags and because of their abundant eurypterid remains are called the Pterygotus beds. In them are found the most perfect specimens of *Pterygotus anglicus*, though complete individuals are rare, and the rock often contains also an abundance of *Parka decipiens*, which has been variously identified as crustacean egg cases and as spores of plants. Above these beds follows the main mass of the lavas upon which rest the beds of Auchtertyre, which

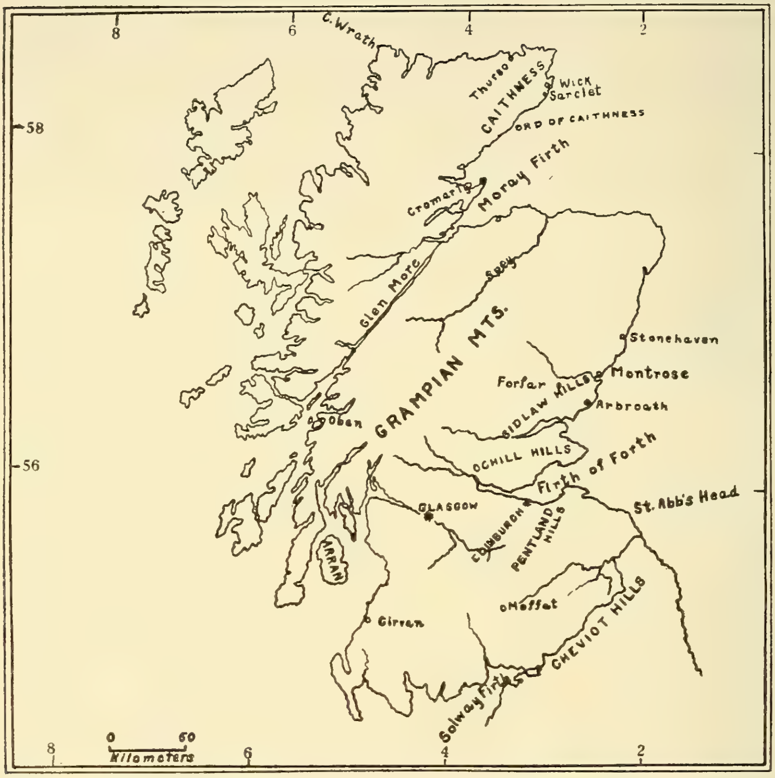

8
6
4
2
58
56
C. Wrath
Thurso
CAITHNESS
Wick
Sarclet
ORD OF CAITHNESS
Moray Firth
Cromarty
Glen More
Spey
GRAMPIAN MTS.
Stonehaven
Montrose
Forfar
SIDLAW HILLS
Arbroath
Oban
OCHILL HILLS
Firth of Forth
St. Abb's Head
GLASGOW
EDINBURGH
PENTLAND HILLS
ARRAN
Moffat
Girvan
CHEVIOT HILLS
Solway Firth
0
60
Kilometers

Fig. 17. Sketch Map of Scotland, Showing Localities where Old Red Sandstone Outcrops

have yielded *Cephalaspis lyelli, Pteraspis mitchelli,* and certain of the Acanthodian fishes. At a slightly higher horizon and contemporary with some of the volcanic beds is the Acanthodian zone which is best seen at Tilliewhamland Quarry, Turin Hill, near the town of Forfar. The list of fossils from these beds cited by Goodchild is as follows (**80,** 597):

Mesacanthus mitchelli
Ischnacanthus gracilis
Climatius scutiger
C. uncinatus
C. reticulatus
Parexus recurvus
P. falcatus
Euthacanthus mitchelli
E. elegans
E. gracilis
E. curtus
Cephalaspis pagei
C. asper
Thelodus pagei
Pterygotus anglicus
Stylonurus ensiformis
Parka decipiens

Just above the top of the volcanic series has been found a fossiliferous zone yielding myriopods among which are Kampecaris and Archidesmus, as well as some poorly preserved plants referred to *Psilophytum robustum.* The top of the Caledonian Old Red is formed by the Strathmore sandstones which are well developed in the Strathmore lowland of Forfar, but the exact age of which is difficult to determine because of the lack of fossils. It has been thought that they might be contemporaneous with the oldest beds of the Orcadian division, but conclusive evidence is lacking.

The Siluric Stonehaven beds of red sandstone and interbedded bright red shales are exposed in the neighborhood of Stonehaven and are about 1500 feet thick. Upon these follows the Dunnottar conglomerate, 5000 feet thick, of coarse red and grey sandstones, grits and conglomerates in which occur pebbles which commonly "range up to a foot or more in length, and yet are astonishingly well rounded. They mostly consist of quartzite" (**117,** 399). Interbedded lavas occur in the top of the series and are succeeded by the Carmylie beds, about 1000 feet thick, of compact red or grey sandstones with some flags, which are the Acanthodian beds described by Goodchild and which contain the abundant fish and eurypterid remains. This series, together with the contemporaneous lavas, forms the backbone of the Sidlaw Hills. It grades up into the Cairnconnan series of 2000 feet of dull red or grey grit with bands of conglomerate. The succeeding Red Head series, 1500 feet thick, consists in the lower part of "fine red thin-bedded sandstone with bands of hard bright red shale, while the upper portion is made up of thicker-bedded sandstone." Six or seven miles south of the Red Head promontory from which the beds are named, there is a lithological change to blue or grey shales with sandstone partings, illustrating well the rapid lateral variation. Overlying this group is the Auchmithie conglomerate. "The series consists of three main masses of conglomerate, with intervening sandstones and conglomerates. The pebbles in the conglomerates are well rounded, fairly large (generally 1 to 6 inches, rarely 12 inches), and, as usual, are mostly quartzite" (**117**, 400). This conglomerate is 800 feet thick and is followed by the highest member of the series, the Arbroath sandstone (1200 feet). "Coarse, gritty sometimes pebbly sandstone is its component rock, always red in color" (**117** 400). The succession as here shown in Forfarshire shows beyond a doubt that the sediments could not have been marine. The complete series is shown in outcrops in Forfarshire, extending over about 500 square miles, while within a distance of less than ten miles the outcrops of all of the formations may be seen.

The Orcadian. Over the greater part of northeast Scotland and extending northward to the Orkney and Shetland Islands there is developed a great series of flags, sandstones and conglomerates younger in age than the Caledonian and these have been called the Orcadian by Goodchild. They constitute the Lower Old Red as used by Geikie and were thought by him to have been deposited in the large water body which he called Lake Orcadie. Neither the natural base nor top of the series has been seen and even the highest members are always followed unconformably by the Upper Old Red. It is unnecessary to take up the formations in detail because they do not contain eurypterids. There are three fossil horizons containing, with one exception, only fish remains. These horizons are the Achanarras beds, the Thurso flags and John o'Groats flags.

Goodchild in summarizing the conditions which obtained in Orcadian time says: "There is evidence that, during the time when the Orcadian Old Red was in course of being deposited, normal pluvial conditions obtained for a time. The deposition of ferric oxide in the old area of inland drainage ceased, chiefly in consequence of the large quantities of vegetable matter which were swept into the old lakes. This latter, in its turn, decomposed the solutions of sulphate of lime, and liberated the calcareous matter, which in a state of diffusion, or aggregated into nodules, now forms so conspicuous an element in the Orcadian Rocks. Furthermore, the sulphate of lime, in its turn, converted the vegetable matter into the bituminoids, which, in a diffused form, permeated—one might almost say saturated—so much of the Caithness Flagstones. I hold, therefore, that the exceptional durability of the Caithness flagstones, which of course is due to the large percentage of bituminous matter they contain, is due to the fact that conditions of inland drainage, one of the phases of desert conditions, prevailed where these occur during the Devonian Period" (**80**, 220).

THEORIES OF DEPOSITION. From data of the type just given, three theories have been evolved, each based upon practically the same observations in the field, but each involving very different interpretations. The oldest and most widely accepted explanation for the Old Red sandstone is that it is a series of lake deposits; the second theory, which quite rightly has never received very much attention, is that of marine deposition; the newest hypothesis is that the Old Red is dominantly of fluviatile origin and that the deposits were not laid down in any permanent body of standing water, either marine or fresh, but largely on the dry land as torrential and flood-plain deposits or in evanescent playas. I shall briefly consider the first two theories and the objections thereto, and shall then give the third and some of the evidence favoring it. All geologists are agreed that the sediments are clastic, that they were not deposited in the deep sea, that they are land-derived and river-transported; the only point of difference that has arisen is in regard to the locus of deposition.

Deposition in Lakes. This theory has been most fully expounded by Geikie and has been generally accepted in the form in which he gave it. For the British area he recognized five lakes on the basis of the present outcrops, considering that the heavy conglomerates marked the rocky lake shores of Devonic time, while finer deposits pointed out the central portions of the lakes. The presence of desiccation fissures and other structural features to be mentioned below was taken as indicative of the mud flats along shore, which were from time to time inundated by the waters of the lake. Plant, insect, and crustaceous remains, as well as the abundant fish fauna, were correctly pointed out as showing the near presence of land. The distinctness of the fish and merostome faunas in the Caledonian and Orcadian rocks was cited as proof of the distinctness of the lakes in which these organisms had lived. It is surprising, and therefore, worthy of note, that Geikie came so very near to the recognition of the Old Red fish and eurypterids as river dwellers that one marvels at his not having reached that conclusion. The arguments which he cites to account for the differences of the ichthyic fauna of his Lake Orcadie and Lake Caledonia, which were supposed to have been separated by the Grampians, are illustrations taken from modern river faunas; and, if application were made directly to the Old Red faunas, one would have to say that the fish in the two Devonic lakes were different because they came from rivers whose headwaters were separated by a divide. I shall give Geikie's statement in order to show how near he came to the discovery that the Old Red Fauna came from the rivers, and how he failed to realize this because he was so intent on the theory of lakes.

"In the second place," he says, "there does not seem to be any valid reason why the ichthyic fauna of two adjacent but completely disconnected water-basins should not have differed considerably in Old Red Sandstone times, as they do at the present day. Even in the same river-system it is well known that the fishes of the higher portions of the basin are sometimes far from corresponding with those in the maritime parts of the area. Neighboring drainage-basins, divided by a comparatively unimportant watershed, sometimes show a remarkable contrast in their fishes. This has been well pointed out by Professor E. D. Cope, in a suggestive paper "On the Distribution of Fresh-water Fishes in the Alleghany Region of South-western Virginia."[13] The James and Roanoke rivers descend the eastern slope of the continent and discharge into the Atlantic. In their upper waters they have only four species of fish in common. In the upper waters of the rivers Holston and Kanawha, which flow south-westwards into the Mississippi basin, there are only two species alike. Between those eastern and western pairs of rivers runs the more marked water-parting of the Alleghany chain. Out of fifty-six species of fish obtained from the head waters of the four rivers, five were found by Mr. Cope on both sides of the water-shed. There is likewise considerable disparity in the genera represented in the different rivers. The still more important barrier of the Rocky Mountains separates ichthyological areas yet more sharply marked off from each other. Such isolated basins as Lake Baikal, Lake Titicaca, and the Caspian Sea show by their peculiar assemblages of fishes how much ichthyic types may be modified by prolonged isolation. The differences, therefore, between the fauna of Lake Orcadie and Lake Caledonia during the Old Red Sandstone, as I venture to hold, are not incompatible with the idea that the two lakes were in a general and geological sense contemporaneous, though separated from each other by the barrier of the Grampian Mountains, which formed an effectual boundary between two ichthyic faunas" (**71**, 364, 365).

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[13] *Journ. Acad. Nat. Sci., Philadelphia*, vi, 2d series (1860–69), p. 207.

Deposition in the Sea. To certain geologists it will appear that I am wasting paper in setting forth a theory which has as its thesis the deposition of the Old Red sandstone in the sea, and that it is a further useless expenditure of ink and of the reader's time for me to voice the objections to such a theory. Indeed, I would agree with anyone who raised such a protest were it not for the deplorable fact that there are still not a few geologists who claim that this much-talked-of red sandstone was deposited in the sea, and further that other sandstones with similar striking lithological and faunal characteristics could have been formed nowhere else but in that region where all sediments have been deposited since the world began, namely, in the littoral zone of the sea.

The chief advocates for the theory of marine deposition are Macnair and Reid who brought out two papers in the *Geological Magazine* for 1896, one entitled "On the Physical Conditions under which the Old Red Sandstone of Scotland Was Deposited" (**159**), and the other "Palaeontological Considerations on the Old Red Sandstone of Scotland," (**160**), in which they sought to prove that physical, stratigraphical and palaeontological evidence all pointed to the marine origin of the Old Red. In a few words their interpretation may be summarized: in pre-Devonic time there was a large land-mass to the northwest of Scotland which supplied the material for much of the marine deposits during Cambric, Ordovicic and Siluric time. At the end of the Siluric the sea began to transgress across Scotland and the land-mass was at the same time depressed until by sinking and by marine erosion the whole area disappeared beneath the sea and the

Upper Old Red sandstone was deposited over the whole of Scotland. In the words of the two authors mentioned above, "The great mass of this mountain chain, then, must have lain to the northwest of the present Old Red Sandstone area, and we now proceed to show how after this long period of upheaval the mountain mass once more began to sink below the level of the sea, and that gradually the waters of the Old Red Sandstone sea levelled it down to the very core" (**159**, 109). They consider that all of the deposits were made along shore, but they are then confronted by the problem of the lack of molluscs and other typical marine forms. This absence they thus account for: "The solution of the problem rather lies in the fact that the presence of peroxide of iron in these rocks is inimical to the preservation of fossils with a calcareous test, and that more especially in the case of sandstones, which even when composed of pure sand are well known to be a bad medium for the preservation of molluscan and other similar organic remains" (**159**, 116).

OBJECTIONS TO LAKE AND MARINE THEORIES. Each of the two theories given can explain some facts which the other cannot; but, on the other hand, each has very serious faults due in some cases to incorrect observations, in others to the acceptance of prevalent ideas and in others to unjustifiable deductions. Both theories contain elements of truth, but both are open to many objections. These fall into two groups: (1) Physical, (2) Faunal.

(1) *Physical.* (a) Red color. Within the last twenty years students of sedimentation have clearly shown that it is impossible for a widespread and thick series of red clastic deposits to be laid down in the sea. The red color, as is well known, is due to the dehydration of sediments which were thoroughly oxidized at the time of deposition. Such oxidation cannot take place under water, but only during exposure to the air. It is not to be supposed that the beds were red when deposited, but that only after dehydration had taken place by the lapse of a long period of time, or through the effect of heat from the interior of the earth, or by pressure was the red color taken on. Of course, certain red beds may receive their final working over under water, but such deposits will be of limited thickness and areal extent. For instance, the Bays sandstone (Upper Ordovicic) of Tennessee, Virginia and adjoining regions is a red calcareous sandstone with a maximum thickness of 1500 feet. Throughout most of the formation organic remains are absent, but in the lower beds marine fossils occur abundantly in a few layers of the red sandstones. These

fossils are all mollusca and brachiopods, are numerous and well-preserved, a fact not compatible with the reasoning of Macnair and Reid. As has been fully explained by Grabau, the main mass of the Bays represents an alluvial fan spread out on the land and having its western and southernmost margins extending into the sea. Thus it was possible for some of the highly oxidized sands to be carried out to sea, where they were deposited and where marine fossils were entombed with them. There is, therefore, nothing inherent in potential red deposits to prevent marine shells from being preserved in them; the difficulty lies in the fact that great thicknesses of potential red beds can not be deposited under conditions where it is possible for marine animals to leave their record, because such deposits must be formed on the land. As for the inimical effects of iron peroxide, it need only be stated that the reddest of deposits contain only a small amount of iron[14] and that it is not the amount but the fineness and perfection of dissemination of the iron that are responsible for the color (Grabau, **87,** 621). That sandstones made up of grains of pure silica are bad media for the preservation of molluscs is easily disproven, for one need only recall such highly fossiliferous formations as the Oriskany sandstone and the Schoharie grit of the Devonic of New York, or the Miocenic sands and conglomerates of the Vienna Basin. The reason why so many sandstones are unfossiliferous is generally that they were deposited as terrestrial sediments either fluviatile or eolian.

(b) Marine denudation. A second argument advanced by Macnair and Reid is based upon the assumption that the erosion of the Siluric rocks in the Highlands of Scotland was due to marine denudation and upon faulty observations at certain localities. They argue "The marine denudation of the Silurian rocks of the Highlands of Scotland is not in dispute, but Ramsay and Geikie have assumed a subsequent lake or fresh-water denudation." The conformable deposition, however "of the Old Red Sandstone upon the preceding Upper Silurian deposits in the counties of Edinburgh and Lanark, the Welsh area, and in the St. Lawrence basin, precludes any such idea; for from the base of the Upper Silurian to the top of the Lower Old Red sandstone the sequence of these deposits is unbroken. It therefore follows that the denudation of the rocks of the Highland area being marine, the equivalent deposits occurring in the Upper Silurian and Lower

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[14] The bright red Vernon shale (Salinan) has shown on analysis only 2.25 per cent of ferric oxide and 0.75 per cent of ferrous oxide.

Old Red Sandstone are equally marine "(**160**, 221). The chief objections to this theory of marine denudation continuing from the beginning of Upper Siluric to the end of Lower Devonic time, fall into three groups: (1) *Tectonic.* The tectonic relations between the Old Red sandstone and the underlying rocks show that there was profound folding at the end of the Siluric, followed by a long period of erosion before the earliest Old Red sediments were deposited; therefore the two series are not conformable as claimed by Macnair and Reid. (See further p. 173 above). (2) *Lithologic.* (See below, sections (d), p. 182, and (1), (2), (3) on p. 189). (3) *Faunal.* (See below, section (b), p. 191).

(c) Salt indicative of marine deposition. The argument that the presence of a salt-bearing stratum in the Old Red at one locality is undoubted evidence of the marine origin of that bed, is of no value unless supported by critical data on the chemical composition of the salt and associated salts if any are present, and on the organic content. Too much is now known concerning the continental origin of many and perhaps the larger number of past and present salt deposits for anyone to claim that the sea was always or even commonly the immediate source of the material. Macnair and Reid would make the presence of the salt band an *a priori* reason for its marine origin, for they say: "We find in the Moray Firth area a large stratum of yellow *saliferous* sandstone, interbedded with shales containing remains of Old Red sandstone fishes . . . . and we think that but one conclusion alone can be drawn therefrom—that the formation and its contained fish remains were marine" (**160**, 221). This type of reasoning is delightfully ingenuous and one that is met with frequently; while the authors do not explicitly state any reason why the salt is marine, the reader yet receives the impression that the presence of fish remains carries a strong presumption, and thus we have the pleasing circle: "The salt is marine because associated with fish, and the fish are marine because found in bands interbedded with salt-bearing sandstones." This whole argument would fall to the ground were anyone to show that the fish were fluviatile, or that the salt could have some other origin.

(d) Thickness of deposits. The recurrence in the same place of thick boulder and pebble conglomerates interbedded with sandstone and shales, all being dominantly red and showing a complete absence of unequivocal marine fossils such as brachiopods, molluscs, crinoids, and trilobites, and amounting in thickness to many thousands of feet proves conclusively that the beds could not have been deposited by an advancing sea, as contended by Macnair and Reid, nor yet in a lake, as Geikie holds. It is not even necessary to point to the red color or to the absence of marine fossils; the thickness and coarseness of the deposits absolutely precludes the possibility of their having been formed in the sea. Macnair and Reid hold that the sea transgressed from the south to the north, but in that case, while there might well have been a basal conglomerate a few feet thick, this would inevitably have been succeeded vertically by finer deposits, sands at first and then muds or limestones as the water became deeper, and the zone of coarse near-shore deposits would have advanced *pari passu* with the transgression of the sea. Thus it would have been impossible for coarse material to have been deposited in southern Scotland in the Upper Devonic when the sea shore stood two hundred miles to the northwest. Greater obstacles arise if we attempt to have these deposits formed in lakes or epicontinental seas. In Forfarshire, the position of "Lake Caledonia," the estimated thickness given by Hickling is 12,500 feet, including the volcanics, or considerably over 10,000 feet of clastic deposits; in Caithness Geikie estimates the series which he supposed to have been contemporaneously deposited in "Lake Orcadie" at 16,200 feet. These two lakes were separated by the Crystalline Highlands, a strip of land about 90 miles broad, which apparently supplied the sediments for Lake Orcadie. The waves of this great lake, which is estimated to have had at its maximum a surface of about 48,000 square miles, cut back into this old mountain chain which was at the same time being denuded by the rivers which brought their loads into the lake. In its maximum developed Lake Orcadie extended from Nairn to the Shetland Islands, the Orkneys representing a sublacustrine rise. The cross section made by Geikie is here reproduced in order to show his interpretation (fig. 18). It is at once apparent that there was not enough dry land to supply the thousands of feet of flagstones making up the Caithness series. It is even more difficult to surmise whence came

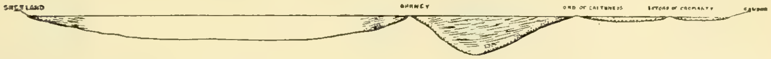

FIG. 18. SECTION TO EXPLAIN THE DEPOSITION OF THE OLD RED SANDSTONE IN THE NORTH OF SCOTLAND
(After Geikie)

the material which filled up the mid-Scottish basin or "Lake Caledonia," for it was hemmed in on the west by a narrow ring of hills separating it from "Lake Lorne" in North Argylshire, and on the south by hills along an east-west line through the Firth of Forth, and on the north by the Highlands which were the source of the 16,000 feet of sediments deposited in Lake Orcadie, while to the east the sea covered France. The only other source would be a mountain chain in the present English Channel, but the objections to this are obvious. A natural question that arises often in reading Geikie's monograph, and one which Macnair and Reid most pertinently ask is how outliers of conglomerates on the tops of high mountains, in the very regions which were supposed to have been lake barriers, are to be accounted for. Geikie has proposed that perhaps they represent old fiord-like indentations in the shoreline. This explanation will not serve, however, when such outliers are found on what must have been the very centre of the ridge between Lakes Orcadie and Caledonia, such, for instance, as Macnair and Reid mention at Mealfourvonie just north of Loch Ness in Inverness where an outlier is found 2284 feet above sea-level, and at Tomintoul in Banff, and Rhynie in Aberdeen. The outliers in all parts of Scotland indicate that the deposit was essentially continuous, though varying in lithological character and origin from place to place.

(e) Structural features. The cross-bedding, ripple marks, and other structural features that are cited by some authors as indicative of marine littoral conditions of sedimentation, by others as lacustrine littoral, will be considered below under the third theory of the origin of the Old Red sandstone (p. 189).

(2) *Faunal.* Attention should be called to certain erroneous lines of argument that have been used and which fall down because based on false premises. For instance, it is impossible to prove that the Old Red sandstone eurypterids were marine by saying that the Siluric ones were and that therefore the Devonic ones of the same genera must also be. First it must be proved that the Siluric eurypterids were marine. To quote once more from Macnair and Reid: "We have . . . . seen no reason assigned why Eurypterids and Placoderms of the same genera, which are marine in the late Upper Silurian, and fishes of the same genera and species which are equally marine in the Devonian of Russia and Central Europe, as well as in the Devonian of North America, should be termed equivocally marine in the Old Red sandstone" (**160,** 219). It may be remarked that the

Devonic fishes of North America here referred to have been shown, from their occurrence and distribution, to be mostly if not entirely fluviatile (Grabau **87, 88**).

Macnair and Reid have with great justification brought forward many objections to the "Lake theory" advocated by Geikie, but their logic fails them when they contend that because the Old Red fish and eurypterids could not have been lacustrine forms, therefore they must have been marine.

The river origin seems never to have occurred to these two writers, or else if it did they considered that the same objections were open to it as to the lake origin. One of the arguments which they advance against the lake theory is the difficulty of the origin and distribution of the fish and eurypterids. They argue thus: these forms were present in the Siluric and so it is not strange that they should occur also in the Devonic; "but of the genera Osteolepis, Dipteris, Glyptolepis, and other fishes of the Old Red Sandstone no undoubted plates or scales occur in the preceding formation. The question therefore arises, whence came these highly organized fishes of the Old Red Sandstone? More especially, from what fresh-water region did they migrate? Not only so, but as the same genera of fishes occur in the Devonian of North America and the St. Lawrence basin, we have an equal right to know by what fresh-water pathway of distribution they were enabled to migrate some 3000 miles between one point and another" (**160,** 218, 219). But surely such facts of distribution should not be distressing; many a case could be cited in the recent fresh-water fish fauna of the same genera occurring more than 3000 miles apart, and with perhaps no related genera in the intervening area. One may mention the case of the genus Umbra, a form so peculiar as to be made the type of a family in which are only two species, these being most closely allied, and yet one occurs in the rivers of the Atlantic states of North America and the other in the Danube system, some thousands of miles distant. Even more remarkable is the genus Scaphirhynchus among the sturgeons, which likewise has two species: one in the Mississippi system, the other in Central Asia. In the same family is the genus Polyodon, with two species only, one in the Mississippi, the other in the Yangtse-kiang. But one need not confine the illustrations to *genera* which are identical in distant regions; *species* offer even more surprising examples. *Perca fluviatilis, Gastrosteus pungitius, Lota vulgaris, Salmo salar,* and many others might be mentioned, inhabiting both the rivers of eastern North America and of Europe. For an extended discussion on migration the reader is referred to chapter V on that subject below, especially pp. 203–7. These illustrations will suffice to show that fresh-water forms can often migrate for several thousand miles, and that through river distribution even the same species may occur in regions widely separated. It may here be remarked that distance is of less significance than time available for migration (see below, pp. 208 *et seq.*).

Summary. The objections to the marine and lacustrine theories of deposition for the Old Red may be reduced to the single criticism that they are out of date. The theories were helpful attempts toward the solution of one of the big problems in stratigraphy, but in their formulation and working out, their authors naturally followed the ideas which were accepted as correct twenty years ago; that some of these should have been found to need revision is only an evidence of the progress of science. The study of sedimentation is a branch of geology which is even yet not receiving the attention due it, but, nevertheless, the students of lithogenesis are steadily increasing, and there is more being said and written today about the work of the wind and of rivers in the geological past than there was a dozen years ago.

Theory of Fluviatile Deposition. The conditions up to the beginning of Old Red sandstone time have already been outlined and it was shown that there was a progressive retreat of the sea to the south, leaving all of Scotland and most of England a region of dry land subject to the subaërial forces of denudation, the greatest of which are the winds and the rivers. The rivers cutting down into the newly elevated continent carried great quantities of detritus toward the sea. But these were not the rivers of a pluvial climate. They were rather the torrents which carried off the waters from occasional heavy rains such as occur in semi-arid regions. That the climate must have been relatively dry is indicated by the thickness and great areal extent of the Old Red Sandstone, for, as was explained, these deposits must have been thoroughly oxidized at the time of their deposition in order that they might be potentially red. In post-Devonic time, either by age, heat or pressure, those oxidized deposits became red through dehydration. The climate, then, was semi-arid and the rivers of the nature of torrents which could transport vast quantities of material, but which would in most cases drop that material before reaching the sea. This would be brought about because the streams would soon lose their supply of water, for the rains were only periodic and even the water which was collected into streams would be lost by evaporation or by sinking into the ground. Great alluvial fans were spread out, consisting of coarse conglomerates near the source of supply and of sands farther away. During those periods when the infrequent but heavy rains fell, playa lakes undoubtedly were formed, similar to those known to be characteristic in present semi-arid regions which have periodically inundated river flood plains. Evidence is not wanting that just such water bodies did form, for Geikie has called attention to certain characteristics in the Thurso flags which admit of no other interpretation. Along the northern coast of Caithness from Castletown to Thurso, a distance of some seven miles along the beach, these flagstones are exposed in great sheets. They consist of "fissile, calcareous, grey, hard flagstones, green, gray and brown calcareous (and frequently bituminous) shales, with thin bands of calcareous gritty sandstone and argillaceous limestone ('calmy limestone'), seldom more than a few inches in thickness. . . . . Even when split into smooth sheets an inch or less in thickness, these hard, tough layers show on their yellow, weathered edges successive paper-like but mutually adherent laminae. . . . . "

A second feature is "the extraordinary abundance of ripple-marked surfaces and sun-cracks. Though these markings abound also in the lower flagstone group, it is here that they attain their greatest development. Surfaces of flagstone or shale, many square yards in extent, are profusely covered with fine ripple lines as sharply preserved as if only today imprinted on the soft sediment. In many places every successive stratum or leaf of rock is thus marked, so that several distinct rippled surfaces may be counted in the thickness of a few inches of rock. It is likewise observable that the rippling is generally close-set, sometimes not exceeding an inch in breadth from crest to crest of the ridges."

Mud-cracks form a third important structure. Geikie says: "More abundant and admirable illustrations of sun-cracks could hardly be found than occur along the coast. Broad, gently-inclined sheets of rock again and again present themselves to view so covered with reticulations as to look like tessellated pavements. It may be noticed that the cracks not infrequently descend through many of the fine laminæ of deposit for a depth of 5 or 6 inches with occasionally a breadth of 3 or 4 inches. The material filling up the interstices abounds with small, occasionally curved pieces of shale. These may, no doubt, be regarded as portions of the upper muddy layer which cracked off and curled up during desiccation, as may often be observed on dried-up pools at the present time. Some pittings, occasionally seen on the sun-cracked surfaces, may perhaps represent rain-drops" (**71,** 392, 393).

Such characteristics as those just cited have been used by Geikie as proof of the lake shore origin of the beds and by other writers as indicative of their formation in mud-flats along the sea coast. Were it not that such interpretations are offered by the majority of geologists it would be unnecessary to dwell upon the unequivocal interior continental origin of these features. That mud-cracks should be formed over wide areas indicates beyond a doubt the presence of a large body of very shallow water which completely evaporated, leaving the whole surface exposed to the air. Not only that, but the exposure must have been long for the cracks to be 5 or 6 inches deep and occasionally 3 or 4 inches wide. Professors Grabau and Barrell have discussed this subject of ripple marks and sun-cracks over wide areas in such a convincing and logical manner that it need not be taken up in detail here. In his *Principles of Stratigraphy* Professor Grabau cites the case of the great playa in the Black Rock Desert, Nevada, which forms in a few minutes and covers an area of from 450 to 500 square miles and yet is seldom over a few inches in depth. Russell has described this lake and records that in a few days all of the water may dry up leaving the surface cracked in all directions. "The lake beds then have a striking resemblance to tesselated pavements. . . . . . "—the very words used by Geikie in describing the Old Red flagstones! Grabau says: "Taking the areas of mud-crack formation in the order of their magnitude, the playa surface would probably stand first. Here the entire surface for hundreds of square miles becomes mud-cracked, often to considerable depth, on the complete drying up of the temporary playa lake. Here, too, the conditions for the preservation are most favorable. Not only is the exposure a long one, often the greater part of the year, or for many years, and for much of the time to intense heat, but the chances of proper burial are much greater. Wandering sand dunes may thus preserve the record, dust deposits may fill the fissures, or, at the next flood, sands or muds may be swept into them. In fact, the playa or takyr seems to be the ideal surface for mud-crack record, and one is tempted to refer most mud-cracked strata to such an origin. Certainly where fossil mud-cracks penetrate a formation to the depth of 10 feet, as is the case in the Upper Shinarump (Triassic) shales of Utah, it is difficult to believe that they could be formed under other conditions than those permitting prolonged exposure such as is found only in the playas of the desert, where ten years or more may elapse between rainfalls. . . . . If the playa lake exists for some time it may become stocked with certain forms of organisms, especially types whose eggs or larvæ can be transported by wind or by birds. The small crustaceans Estheria, Daphnia, and Cypris are characteristic of desert lakes, the first being found in ponds which are dry for eleven successive months" (Grabau, **87,** 707, 603). The nature of the organisms characteristic of such playa lakes is exceedingly interesting in view of the fact that Geikie adds to his description of the lithological characters of the beds in question the following statement: "Fragments of fish and coprolite are scattered abundantly through most of the flagstones. Some of the calcareous shales are full of Estheria, while traces of plants occur in great numbers, though generally in a somewhat macerated condition" (**71,** 393). The close correspondence between the description of modern playa deposits and the Caithness flag portion of the Old Red Sandstone series leaves no reasonable doubt that the latter formation was the result of inland drainage in a semi-arid or desert region.

The detailed characteristics of a single series of beds in the Old Red have been taken as an example illustrating the conditions which prevailed, but attention need not be confined to any single part of the formation, for Goodchild has found evidence in all of the divisions of the Old Red to show that desert conditions prevailed throughout all the Devonic wherever this type of deposition obtained. In order not to burden the discussion with a too lengthy description of all of the features indicating desert or at least continental origin for these deposits I shall give a list setting forth the facts already cited and certain additional ones.

Summary of Evidence for Fluviatile Deposits. (a) Lithogenesis. (1) The presence of finely stratified, rippled and sun-cracked flags over an area of many square miles, and at successive horizons, the sun-cracks penetrating to a depth of five or six inches and being at times three or four inches wide, indicates playas or at least broad river flood plain conditions. These features have been noted by Geikie in the Thurso flags (**71,** 392, 393).

(2) The presence of clay galls in the deep interstices between the sun-cracked prismatic layers in the Thurso flags indicates exposure of clayey surfaces to the air long enough for flakes to be curled up and blown into the cracks. Such a feature might characterize any sun-cracked area, but the depth of the cracks as cited in (1) indicates a playa or a river flood plain.

(3) The basal conglomerate of the Orcadian series has characteristics pointing to the fact that it is made up of material derived from the *disintegrated* but not decomposed underlying rocks, thus indicating dry climatic conditions during its formation. The conglomerate is too thick to represent the basal conglomerate formed by an advancing sea, even if other characteristics did not preclude the marine origin. In detail the characteristics are as follows: (a) "The blocks vary in size up to as much as a yard, or even more, in length, and consist of gneiss, pink granite, quartz-porphyry, quartz-rock, mica-schist, and other crystalline rocks, with abundance of pink cleavable orthoclase derived from the underlying gneiss" (**71**,375). In the Caledonian series the blocks are even larger, Hickling having recorded them up to 8 feet in diameter. (b) In every case the underlying rock from which the conglomerate boulders were derived can be found not far away. "Near the granite they (the boulders) are made up in great measure of granitic debris. Round the quartz rock they are largely composed of that material. The existence of the well-veined orthoclase gneiss is indicated some distance before the underlying rock is actually seen by the abundant fragments of beautifully cleavable pink felspar in the conglomerates" (**71**, 370). (c) In both of the quotations just given reference is made to the abundant presence of fresh pink orthoclase. Goodchild has likewise referred to the arkoses with unweathered feldspar fragments (**80**, 219), and has pointed out that they indicate disintegration under semi-arid or desert conditions. (d) The basal conglomerate is too thick to be of any other than fluviatile, more especially torrential origin. For instance at Sarclet, about five miles south of Wick, Caithness, a great mass, 250 to 300 feet high, rises from the sea, the base not being visible. Here "the matrix, red in colour, and less strongly felspathic than towards the south, contains large and usually rather well water-worn fragments of quartz-rock, granite, felspar, porphyry, and red sandstone" (**71**, 376). On no sea or lake beach is a large boulder conglomerate 250 feet thick ever formed by the action of waves.

Along an open coast exposed to the full force of the waves great boulders may indeed pile up, but they will be in a very narrow strip at the foot of the cliffs and will rapidly decrease in size until within but a few feet from shore no large ones will be found and those which do occur will be in only a thin layer wedging out seaward. Moreover, a boulder conglomerate formed along a seacoast would almost certainly be fossiliferous, as I shall point out below. Such a conglomerate might, however, easily be piled up by the waters of the swift and powerful torrents which periodically occur in desert regions. In large basins of inland drainage the rivers flowing down the enclosing mountains bring in great quantities of debris which is coarse and bouldery near the mountains and finer further out. Davis records that "A great part of Persia consists of large basins enclosed by mountains and without outlet to the sea. Long waste slopes stretch forward five or ten miles with a descent of 1000 to 2000 feet, stony near the mountain flanks and gradually becoming finer textured and more nearly level. The central depressions are absolute deserts of drifting sands with occasional saline lakes or marshes" (**87,** quoted from Davis, **50,** 588).

(b) Faunal. Throughout the Old Red sandstone of Great Britain and the continent, typical marine organisms are absent except where this facies interfingers with the Devonic marine facies. The types of life represented in this whole series are few and yet of exceeding interest, since they are among the earliest of land forms, such as scorpions, insects, freshwater crustacea, fish and eurypterids, while the flora, though much poorer than that from the Gaspé sandstone of New Brunswick, yet shows the presence of ferns, coniferous trees and vascular cryptogams. The Caledonian Old Red, which is largely conglomeratic, has yielded comparatively few fossil remains, but in the Pterygotus-or Carmylie- sandstones of Forfar, *Pterygotus anglicus* has been found associated with *Parka decipiens* and at a higher horizon Cephalaspis and Pteraspis occur, and still higher the Acanthodian beds of Turin with a good fish fauna as well as *Pterygotus anglicus* and *Stylonurus ensiformis*. Thus, in the Caledonian Old Red, a series 12,500 feet or more in thickness, the fish and eurypterids are the only abundant organisms. This single faunal fact would be sufficient, even though all other types of evidence were wanting, to make me say that those two groups of organisms lived in the rivers (see criteria, p. 77 above). In the Orcadian the fauna is more varied. Traquair, who has made such a careful study of the ichthology of the Old Red Sandstone of Great Britain, has established the following fish zones in the Caithness area (**272**):

John O'Groats	Tristichopterus alatus Egert.
	Microbrachius dicki Traq.
Thurso	Coccosteus minor H. Miller
	Thursius pholidotus Traq.
	Osteolepis microlepidotus Pander
Achanarras	Pterichthys, 3 species
	Cheirolepis trailli, Ag.
	Osteolepis macrolepidotus Ag.

This fish fauna is very different from that to the south of the Grampians in Forfarshire, there being no species in common between the two areas and only two genera, Mesacanthus and Cephalaspis, the latter being represented in Caithness by only a single specimen.[15] From this division no eurypterids have been reported.

In Caithness and in the Orkneys and Shetland isles has been found a phyllopod crustacean of a genus which at present lives in rivers and fresh water lakes and playas, namely, Estheria. T. Rupert Jones has described the species *E. murchisonia*, which is abundant in a "dark grey, tough, fine-grained, sandy flagstone, slightly micaceous, somewhat varying in tint and hardness. . . . . Great numbers of the valves are spread over large surfaces of the flagstone, sometimes scattered sparsely, sometimes congregated in groups, forming films between the layers of fissile stone" (**191,** 405). Murchison says of this species: "It occurs in certain localities in such numbers as to form layers an inch or two thick, entirely made up of the thin carapaces" (**191,** 404).

The Old Red sandstone of Lorne has yielded, besides *Pterygotus anglicus* remains, two species of chilognathous myriopods, *Campecaris forfarensis* (Page) and *Archidesmus* sp. described by Peach (**214,** 83). These are among the earliest myriopods yet known and suggest that the beds in which they were found were formed on land, for if the myriopods had been transported far they would have been destroyed. Moreover, since they had not hard parts to be preserved, they must have been buried quickly. A playa would be the ideal place for their burial, but I do not know enough about the beds in which they were found to state that they were formed in a playa. Macconochie has discovered in these beds plant remains related to Psilophyton, and a fish which Traquair describes as *Cephalaspis lornensis* (Macconochie **157**, Traquair **273**).

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[15] The significance of this fauna has already been discussed in chapter III, p. 92, and the other aspects will be considered below, p. 247, *et seq.*

Geikie calls our attention to what is believed to be "the oldest lacustrine or fluviatile mollusk yet known, *Amnigenia* (*Anodonta*, *Archanodon*) *jukesii*. This shell has been found in the Upper Old Red Sandstone of Ireland and England, associated with land-plants, (*Archaeopteris*, *Sphenopteris*, *Bothrodendron*, *Ulodendron*, *Stigmaria Calamites*) fishes (Coccosteus) and arthropods (Eurypterus).

12. MISCELLANEOUS OCCURRENCES

We have now completed the discussion of the significance of the eleven most important eurypterid faunas, the ones which it has seemed to the writer offered the most material from which to draw deductions. In addition there is a certain group of occurrences which appear to be able to throw little light upon the determination of the habitat, and they have not been discussed so far, for, if from the best material which we have at hand it can be proved that the eurypterids lived in the rivers from the very beginning of their history, then we need be no more distressed at finding a fragment among marine remains than we are when we find a single leaf or piece of wood associated with brachiopods and molluscs. But, lest the advocates of the early marine habitat of the eurypterids should complain that I pass over lightly the very cases which seem to prove conclusively to them that their view is correct, I shall take up those cases briefly and show wherein they do not prove what they are supposed to; but rather if of any weight at all, indicate that the eurypterids did not always live where their remains were entombed. These remaining instances, then, fall into three groups.

(1) The presence of a single eurypterid fragment or perhaps two or three fragments associated in the same stratum with a typical, well preserved, marine fauna.

(2) The presence of a single eurypterid fragment or complete individual in a stratum barren of other fossils, but immediately preceded and succeeded by strata carrying marine fossils.

(3) The presence of quite a number of fragments in scattered occurrence, but associated intimately with a typical marine fauna.

To the first group belong the following:

Echinognathus clevelandi, Utica shale, Upper Ordovicic.

The eurypterid fauna of Condroz, Upper Devonic of Belgium.
Pterygotus problematicus, occurrence doubtful in Aymestry limestone.
Eurypterus punctatus fragments, Wenlock limestone, England.

To the second belong:

Strabops thacheri, Potosi limestone, Upper Cambric or Lower Ordovicic.
Eurypterus prominens, Clinton.
E. boylii, Guelph.
E. microphthalmus, Manlius; Monroe.
Pterygotus problematicus, May Hill sandstone, Llandovery.
Eurypterus sp. Wenlock (of Southern Belt, Scotland).
Eurypterus sp. Wenlock (Girvan area, Scotland).
Pterygotus australis. Upper Siluric of Australia (Information insufficient, may belong to group 1).
Pterygotus osiliensis, Pterygotus marl of Gotland.

To the third group belong:

The Siluric fauna of Bohemia.
The Lockport fauna of Ontario.
The Siluric fauna of Podolia and Galicia probably belongs here.
Pterygotus sp. Siemiradzki, Middle Devonic of Galicia.

The lines of argument for the above occurrences have been stated from time to time, but are scattered throughout the paper. They may be brought together here for reference since so many of the cases are subject to the same arguments. In chapter III the criteria for recognizing the various types of habitats in the past were fully discussed, and will now be of great help in establishing the nature of the habitat indicated by the various eurypterid occurrences given in the three lists above. In the light of the arguments that have gone before, and especially of the discussion on habitats, the following truths may be considered as self-evident or as easily demonstrable.

1. The occurrence of a single fragment, or of two or three fragments, or of a single complete eurypterid in a formation where it is associated either intimately in the same stratum or closely in adjoining strata with a typical marine fauna, as defined on p. 76, cannot be considered as proof that the eurypterid remains are a part of the marine fauna, for the following reasons: (a) it is impossible to explain how any group of marine organisms could have their remains so completely destroyed that but a single fragment should be left; such is

never the case with other groups of marine organisms and it is not logical to suppose that the eurypterids should in so many instances have suffered complete annihilation, leaving only one fragment behind to show that they had lived in the sea of that period. It has been suggested that the eurypterids, like modern crabs and horseshoe crabs, were cannibalistic, not only devouring living members of their own family, but also the molted exoskeletons, in this way destroying most of the hard parts which might otherwise have been preserved. This is an ingenious explanation to account for the fragmentary condition of the eurypterids so frequently observed, but when we attempt to explain similarly the appearance in the rocks at a given horizon, of only one fragment, the result is a *reductio ad absurdum.* For unless we are to believe in a miraculous mutual devouring, such as that which took place between the "Gingham Dog and the Calico Cat" as so vividly described by Eugene Field, we would still expect survivors from the feast. Are we to let imagination run wild and to picture to ourselves a fierce struggle in those ancient seas between the members of the eurypterid family, a struggle which caused the destruction of young and old alike, friends, neighbors, and relatives, until a single maimed, but victorious individual remained? But, if we go so far, we must look at the last scene, must gaze upon the painful sight of that last survivor, demented by his orgies, tearing his own limbs apart and devouring them until—well, we would expect that his jaws and ectognaths would have been the final things to remain, but strangely in the Utica sea it was a claw which remained. It is painful to think of the destruction of the young merostomes in these periodic holocausts, that whole faunas should have perished leaving no descendants, and of the infinite labor Nature must have had to create anew genera and species for succeeding seas! Yet, when the early Palaeozoic periods were past these frightful scenes of wholesale destructon gave way to gentler, more pacific modes of life, so that in the Upper Siluric in central and western New York and on the Island of Oesel we find indications from the fossils that the eurypterids lived amicably to a ripe old age, dying a natural and peaceful death and enjoying a decent and fitting burial in the fine muds of those times. Thus we see again the steady progress in evolution from the early days of barbarism to the later ones of communal altruism. (b) It is impossible to explain the occurrence of one well preserved eurypterid with no other associates, such for instance as *E. prominens;* for, if the conditions for perfect preservation obtained, then the rest of the eurypterid fauna should have been preserved. (c) If we are to consider that a single fragment of a eurypterid when found in marine strata proves that the eurypterid lived in the sea, then, provided no other proof existed to the contrary, insects, land shells, leaves, logs, spiders, scorpions and other land forms which are often floated or blown out to sea and which are found today thousands of miles from land, and have often been met with in the rocks associated with marine forms would also be considered as inhabitants of the sea. Since the reasoning given on pp. 93-193 has shown that the most significant and important occurrences of the eurypterids point to a fluviatile habitat, then the single special cases should not be cited as proof to the contrary. It is just as if we were to say that, in spite of the many abundant, well preserved floras of the order Fagales known throughout the world in continental beds from the Cretacic to the present, we were forced to conclude that birch and oak trees have always constituted part of the open marine flora, because in some dredging operations today an oak trunk and a number of birch leaves were hauled up one thousand miles from shore. Specific instances of anomalous occurrences have been cited on p. 67, but I shall give one further illustration here to show how little association may mean.

The Upper Devonic sandstones of Condroz Belgium with an aggregate thickness of 22 m., constitute the sandy phase of the Famennian shales of the lower part of the Upper Devonic. They are of interest because of the mixed marine fauna and terrestrial flora found intermingled in them; brachiopods, pelecypods, land forms including ferns, and the fish characteristic of the upper Old Red of Scotland are found associated, and the American genus Dictyospongia also occurs in this sandstone. Since at least part of the fauna is marine, and the flora is terrestrial, the eurypterids might be interpreted either as marine or fresh water forms; but inasmuch as only a few fragments have been found, the more rational interpretation would seem to be that the organisms did not live in the sea. This is further borne out by the fact that as the Upper Devonic beds are traced to the south into Germany they become pure marine limestones, in which no eurypterids have been found, but traced to the northwest they merge into the Old Red sandstone of England and Scotland which contains eurypterids and fresh water fishes. The deposits in Belgium, then, mark the meeting-place of the marine and terrestrial waters as the sea encroached from the south upon the Upper Old Red shore, and for this reason it is impossible from a study of the fauna, flora and sediments of that region alone to arrive at any conclusion as to the habitat of one group of the organisms whose remains are found there. If, for instance, we had no information from other sources regarding the ecology of the pelecypods, it would not be safe to infer that they were marine organisms because associated with brachiopods, nor would it, on the other hand, be fair to assume that they were terrestrial because ferns were embedded in the same strata. The same may be said for the eurypterids; nothing regarding their habitat can be inferred from their appearance in such beds as these sandstones with a commingled marine and terrestrial assemblage of organic remains. In some cases it is possible to take account of more factors, such as the relative perfection of preservation of the various groups of organisms when one, perhaps, shows evidences of transporation and consequent maceration, or again, the relative scarcity or abundance of species and individuals. In the instance of the sandstones of Condroz, I think that it is justifiable to attach importance to the sparse and fragmentary condition of the eurypterids as compared with the abundance and good condition of the other organic remains, and to conclude that probably the merostomes did not live in the region where their fragments finally came to rest.

2. The truth of the thesis of the above paragraphs being accepted, it must be acknowledged *a fortiori* that a single fragment or even a complete individual in a stratum in which occur no remains of typical marine organisms, intercalated in strata which do, is not the slightest proof that the eurypterid was an inhabitant of the sea.

I may here, as an illustration, give an account of the occurrence of *Strabops thacheri*, the only known eurypterid from the Upper Cambric or Lower Ordovicic Potosi Limestone of Missouri. In the section near Flat River, St. François Co., Missouri, given by Nason, the Potosi formation is represented as resting disconformably upon the Bonne Terre or St. Joseph limestone of uncertain Cambric age, but probably at least Middle if not Upper Cambric. At the base of the Potosi is an edgewise conglomerate extending upward for about 6½ feet and followed by 100 feet of conglomerates and interbedded slates, the latter carrying several species of trilobites, brachiopods and an occasional *Hyolithes primordialis*. As was stated on p. 13, Beecher, who identified the fossils collected by Nason and who described the one eurypterid found, did not and perhaps could not state in just which layer Strabops occurred and whether it was found directly associated with the marine forms. From a study of the material in the Palaeontological Museum at Columbia University, I have found that the rock in which Strabops occurs is not of the same lithological character as is that in which the other fossils occur. The slab on which the counterpart of Strabops rests is roughly 3 x 9 x 12 inches in dimensions and contains no other organic remains. The limestone containing the trilobites is somewhat finer grained, differing little in color, but being made up of numerous cephala, pygidia and fragments of several genera of trilobites. The difference in faunal character between the two rocks is pronounced. The slab containing Strabops was not collected by the same person nor at the same time as were the other fossils, so that exact data probably will never be obtained. However, the precise association is of slight import. The alternation of limestone conglomerates and shales in the lower Potosi series indicates near-shore conditions of sedimentation, and the occurrence of the single specimen of a eurypterid, far from pointing to a marine habitat for this one individual, militates very strongly against such a mode of life. In all cases the occurrence of a single individual is one of the strong arguments against the assumption that the individual belongs to the fauna of the bed in which it is found. It is far more logical to assume that it has been brought there by some accident, for in Nature we do not find single individuals of any kind of animal in a region far removed from that occupied by other members of its family. Again, the only way to account for this occurrence is to assume that these eurypterids were living in the rivers of that time, and that this individual happened to be carried out into the shallow sea in which the Potosi limestone was being deposited. That the sea was shallow is indicated by the fine stratification of the rock as well as the paucity of the organic remains which are insufficient to have furnished the lime of which the formation is composed. This limestone like others of its kind seems to have been formed from the calcareous sand and mud carried by surcharged rivers coming from limestone regions into shallow sea-border basins.

The merostomes of the Stephen shale of British Columbia are not now recognized as eurypterids, but belong to a distinct order, that of the Limulava Walcott (Clarke and Ruedemann **39**, 410). Hence their association with marine organisms may be disregarded.

3. It may not be quite so clear that the occurrence of a fairly large fauna of eurypterids in a bad state of preservation, but associated

with fossils of marine origin, in no wise indicates that the merostomes were marine. The Siluric fauna of Bohemia is one of the best illustrations of this class, and I shall consider it in detail.

Barrande's work on the faunas of the Palæozoic rocks of Bohemia has conclusively shown that the trilobites and other crustacea, as well as the eurypterids reached their acme in numbers in the Siluric, constituting the third fauna E. The upper part of this showed a far more prolific development of life than did the lower, as is readily brought out by the following figures. In the Lower Siluric (E e_1) Barrande records sixteen species of trilobites and ten species of other arthropods among which he includes phyllopods, ostracods, eurypterids and cirripedes; for the Upper Siluric (E e_2) the corresponding figures are 82 and 24, making a total of crustacea (and eurypterids) for the Lower Siluric of 26, for the Upper 106. Furthermore, the crustacea, though represented by so many species were not the dominant forms of life, for the Siluric, especially the upper part, marked the period of greatest development of the cephalopods which were represented by 665 species. As I stated in an earlier part of the paper, Barrande does not give horizons of smaller taxonomic value than his "bands" which correspond to the first subdivision of the periods, and it is therefore impossible even to approach the niceties of correlation which can be attained in America; one cannot determine the precise level even within several hundred feet for any particular occurrence. However, there is no reason to doubt that all of the Siluric of Bohemia was marine. Considering the nature of the fauna of that period and the number of species which Barrande was able to describe even so early as 1852, his explanation for the fragmentary character of the eurypterids, as due to their having been the food of the cephalopods, seems inadequate. If the trilobites were able to live in the same sea with cephalopods and escape unscathed, so that their remains were preserved in wonderful perfection, why should the eurypterids have been so voraciously attacked? It is doubtful if the eurypterids were of so different an internal nature from the trilobites that they should have been more palatable, nor were their exoskeletons more fragile. In the Siluric sea 814 species of cephalopods are known to have existed, as compared to 97 species of trilobites. Thus there were eight or nine species of Cephalopods to each species of trilobite, while the number of the individuals of the former vastly exceeded that of the latter. Surely in the great struggle for existence which was taking place, the cephalopods, if they fed upon crustaceous animals at all, would scarcely have used such nice selection so that the eurypterids alone were consumed, while the trilobites continued to flourish.

Of a certainty, some more rational explanation must be sought. This occurrence in Bohemia is one of the rare ones in the Siluric in which the eurypterids are found associated with an abundant and unquestionable marine fauna. Yet the facts, that no complete individual has been found, that even the fragments are of so uncertain a character that some which at first were supposed to belong to separate species have with more study been found to belong to the same species, and finally that the eurypterids, of all the myriad organisms which lived in that sea, should have been broken to fragments of which only a few are found—these facts will not admit of explanation on the ground that the eurypterids lived in the sea. They must have lived in some other aqueous realm besides the sea, and one is again led to the conclusion that they must have lived in the rivers. The facts of migration and the relations of the Bohemian forms to those in other parts of the world strongly support this conclusion. (See below chapter V).

CHAPTER V

The Geological and Geographical Distribution of the Eurypterids and the Conditions of Migration

SUMMARY OF FACTS OBSERVED REGARDING THE DISTRIBUTION OF THE EURYPTERIDS

The anomalies in the geographic distribution of the eurypterids constitute one of the most difficult phases of the problem of the habitat. The facts which have been summarized in the tables on pages 37-49, and which have been discussed in various parts of the paper up to this point, clearly lead to the following generalizations: (1) There are many cases in which single individuals are found separated geologically and geographically from other known eurypterids or eurypterid-faunas. (2) The same or closely related species may occur in regions widely separated, although in the same horizon, in intermediate regions, either no eurypterids at all are found or else those which do occur are not related to those in the other localities. (3) Eurypterids are seldom found in the same chronofauna throughout the world, but appear suddenly, now in one place, now in another at different horizons, and continuous widespread faunas are entirely wanting.

(1) As illustrations of the scattered occurrence of single specimens of eurypterids may be mentioned: *Strabops thacheri* in the Upper Cambric, *Echinognathus clevelandi* from the Utica, *Eurypterus prominens* from the Clinton, *Eurypterus boylei* from the Guelph, *Eurypterus microphthalmus* from the Manlius, and *Eurypterus douvillei* from the Rothliegende.

(2) As an instance of the same species occurring in places many miles apart, *Eurypterus remipes* may be cited. This species has been found in Waterville, Oneida County, N. Y. in great numbers; at Jerusalem or Wheelock's Hill, Herkimer County; to the northeast (near Cedarville) and west (Paris Hill) of Jerusalem Hill, near Oriskany; at Cayuga Junction, Cayuga County; and possibly at Buffalo. In all of these localities it has been found in the uppermost part of the Bertie, but at Seneca Falls, Seneca County, specimens have been found in the Rondout Waterlime (which may be possibly of the same age as the Bertie). There are several cases of closely related species occurring in localities separated often by great distances. One example that may be cited is that of *Eurypterus lacustris*, *E. remipes* and *E. fischeri*. For a long time the Baltic form (*E. fischeri*) was identified with *E. remipes* and it was not until Eichwald pointed out the differences in surface sculpturing and certain other characteristics, that the species was made distinct. Clarke and Ruedemann conclude their discussion of the comparion of these two species by saying that, "Altogether, the differences are so small that Schmidt's suggestion that they are but geographical varieties is fully supported" (**39**, 172). They add, further, that *E. remipes* and *E. lacustris* "are more closely related to each other than either of them to *E. fischeri*, indicating that they had but lately separated. Their differences rest mainly in the shape of the carapace and they are duplicated by those between *E. fischeri* and *E. laticeps*, two forms associated in the same [Baltic] rocks" (**39**, 172). *Eurypterus fischeri* has been found in Oesel and in Podolia.

(3) The data on the distribution have brought out clearly the fact that at no geological horizon is there a widespread or continuous eurypterid fauna indicating passageways of migration. Even in the Upper Siluric, which marks the acme in all respects for the eurypterids, the fauna does not show that universality which would be expected of denizens of the sea or of organisms whose immediate

ancestors were marine. The Bertie fauna of North America covers an area of not over 1000 square miles. The corresponding European chronofauna is found in the Baltic Isles and Russian Provinces in sediments similar in lithologic character to those in North America, but the areal extent is small and circumscribed. In the Upper Siluric of Bohemia and of Scotland the eurypterids occur within a very limited area. But in the adjoining undoubted marine formations which lie in the path of migration by marine waters, the eurypterids are wanting. The graptolite fauna of the Ordovicic is known throughout the world, but the eurypterids are found only in the small area around Catskill, New York. Similarly, eurypterids are found in the Wenlock shales and limestones of Scotland, but not to the south in England, nor in other Niagaran formations at the same horizon throughout the world.

The tremendous importance of the geological and geographical distribution of the eurypterids has heretofore been overlooked except by Professor Grabau, who has dwelt upon it in the discussion of the most important occurrences, especially in North America. When the factors of distribution are considered throughout the Palaeozoic and on every continent, it will be seen that they constitute the gravest objection of all to any marine, lagoon, or estuarine theory of habitat that has been advanced. Again we must turn to a contemplation of the present, for we must believe that the laws which control the universe have always been undeviatingly constant and will always remain so. Our great difficulty in reading Earth history correctly lies in our failure to learn the laws; so much of the past appears to our view not in the form of causes but of results. In the study of the phenomena of the present, we are usually privileged to see both the causes and the effects, and thus the opportunity is offered to ascertain the laws, although in many cases our lack of knowledge or our unreadiness, prevents us from taking advantage of this opportunity. Thus we fail to learn and to formulate the laws which are operative in every physical fact and phenomenon, visible or invisible. That man we call a master who has discerned the laws; he alone can interpret with truth the marvels of this world and of other worlds; he alone can prophecy, with a reasonable degree of certainty, the things which are to come; and he alone, if he be a geologist, can reconstruct along the lines of truth the former history of our earth. Therefore, it behooves us to become acquainted with the laws which may be studied today, before we attempt to formulate theories about the conditions which obtained in the past. If there were oceans during Palaeozoic time in which large accumulations of clastic material were forming, we are drawn to the reasonable conclusion that there were land masses from which this clastic material was derived. We must also conclude, if we view the matter rationally, that there must have been rivers on those ancient continents and that then, as now, they constituted the principal agents of transportation of material into the sea. And finally, we must believe that if there was any life in those rivers, it must have been subject to the same laws of dispersal as is the life in the rivers today. My statement does not say that because we have life in the rivers now there must have been life in the Palaeozoic rivers; that is obviously untrue. But if there *was* life in those rivers, then it was subject to the same laws which are operative now. It is advisable, therefore, to consider these laws and to formulate them that we may have certain definite principles for future reference.

MIGRATION AND DISPERSAL OF RECENT FLUVIATILE ORGANISMS

Of existing taxonomic groups, the fish have received more study than any other group of fluviatile organisms, and interesting as well as exceedingly pertinent data are at hand in regard to migration and dispersal of this group. Günther in his *Study of Fishes*, makes the general statement that: "The Freshwater fishes . . . . . have been spread in *circumpolar* zones, and in but a limited degree from north to south. No family, much less a genus, ranges from the north to the south, whilst a number of families and genera make the entire circuit round the globe within the zone to which they belong. Not even the Cyprinoids and Siluroids, which are most characteristic of the freshwater fauna of our period, are an exception to this. Temperature and climate, indeed, are the principal factors by which the character of the freshwater fauna is determined; they form the barriers which interfere with the unlimited dispersal of the ichthyic type, much more than mountain ranges, deserts, or oceans" (**97**, 215).

A few illustrations of this widespread dispersal of fishes in circumpolar zones will show that the above statement is not merely theoretical. These illustrations are selected, but taken verbatim from Günther's work (**97**, 209–211).

A. SPECIES IDENTICAL IN DISTANT CONTINENTS. 1. A number of species inhabiting Europe and the temperate parts of eastern North America, as *Perca fluviatilis*, *Gastrosteus pungitius*, *Lota vulgaris*, *Salmo salar, Esox lucius, Acipenser sturio, A. maculosus*, and several Petromyzonts.

2. *Lates calcifer* is common in India as well as in Queensland.

3. *Galaxias attenuatus* inhabits Tasmania, New Zealand, the Falkland Islands, and the South American continent.

B. GENERA IDENTICAL IN DISTANT CONTINENTS. 1. The genus *Umbra*, so peculiar a form as to be the type of a distinct family, comprises two most closely allied species only, one of which is found in the Atlantic States of North America, the other in the river system of the Danube.

2. A very distinct genus of Sturgeons, *Scaphirhynchus*, consisting of two species only; one of these inhabits the fresh waters of Central Asia, the other the system of the Mississippi.

3. A second most peculiar genus of Sturgeons, *Polyodon*, consists likewise of two species only, one inhabiting the Mississippi, the other the Yang-tse-Kiang.

4. *Amiurus*, A siluroid, and *Catastomus*, a Cyprinoid genus, both well represented in North America, have a single species each, in temperate China.

5. *Lepidosiren* is represented by one species in tropical America, and by the second in tropical Africa (Protopterus).

6. *Galaxias* is equally represented in South Australia, New Zealand and the southern parts of South America.

C. FAMILIES IDENTICAL IN DISTANT CONTINENTS. 1. The *Labyrinthici*, represented in Africa by 5, and in India by 25 species.

2. The *Chromides*, represented in Africa by 25, in South America by 80 species.

3. The *Characinidae*, represented in Africa by 35, and in South America by 226 species.

4. The *Haplochitonidae*, represented in southern Australia by 1, in New Zealand by 1, and in Patagonia by a third species.

The facts regarding the distribution of freshwater fish show that it is not uncommon for identical families, genera and even species to be found living in rivers on opposite sides of the world without any known relatives in the intervening rivers. There seems to be no limit to the distance which freshwater fish may migrate in the same circumpolar zone; while even mountains, deserts, or oceans, do not offer absolute barriers. It is thus easy to see that migrations which would be impossible for marine forms offer no difficulties to freshwater organisms, and localized occurrences which would be inexplicable for the former are easily understood for the latter. I do not mean to imply that migration of river forms all around the world can take place always in a single geological period. It is well known that certain related or identical species of fish which today are found in rivers thousands of miles apart have such a distribution because their ancestors in a former geological epoch when relations between land and sea were different had an opportunity to accomplish the migrations, all evidences of which have since been destroyed. In distributions observed today we see the result of migrations which may have taken place ten thousand or ten million years ago. Thus Günther observes that the present occurrence of the *Dipnoi* on the continents of Africa, South America and Australia is consequential upon their wide range in the Palæozoic and Mesozoic, while that of the Siluroids, which have an even greater range, is the result of their distribution during the Cenozoic. It may be well to refer here to the theory of the independent origin of specific characters, in widely dispersed organisms, which are, nevertheless, placed under similar or identical physical conditions. This theory has been especially applied to the fishes of South America by Hasemann (**110**), who has shown how further complications arise through the production of apparently identical though actually unrelated species in response to similar environmental complexes.

SUMMARY. Observations upon freshwater fishes have brought out the following facts as to dispersal and migration:

1. Dispersal and migration take place in circumpolar zones the range of migration depending upon: (a) temperature, (b) climate, (c) euryhalinity or stenohalinity of species, genera, etc., (d) vitality of given individuals to withstand sudden changes in temperature, in salinity, or in the amount of available water and food supply.

2. The interlacing of the headwaters of mighty river systems oftentimes accounts for the occurrence in the lower reaches of rivers hundreds of miles apart of identical or closely similar genera and species. The case of the trout on the North American continent is a familiar illustration. In the interlacing headwaters of both the Columbia and Missouri rivers occurs the cut-throat trout, *Salmo clarki*. Various species are gradually differentiated away from the headwater region. Thus the nearest relatives of *S. clarki* are *S. virginalis* in the basin of Utah, and *S. sternias* of the Platte River. "Next to the latter is *Salmo spilurus* of the Rio Grande and then *Salmo pleuriticus* of the Colorado. The latter in turn may be the parent of the Twin

Lakes trout, *Salmo macdonaldi.* Always the form next away from the parent stock is onward in space across the barrier" (Jordan, **134,** 547). Migration from the headwaters of one system to those of another only a few miles distant is accomplished: (a) as a result of river capture, (b) by the accidental transportation of the eggs of fishes, by birds, from one stream to another, (c) by the temporary formation of connecting streams or lakes between two river systems in a period of torrential rains, (d) by the temporary or permanent shifting of the watershed between two systems by a slight geological change, (e) by actual migration of fishes over areas where there are not continuous waterways. "Some fishes, provided with gill-openings so narrow that the water moistening the gills cannot readily evaporate; and endowed, besides, with an extraordinary degree of vitality, like many Siluroids (*Clarias, Callichthys*), eels, etc., are enabled to wander for some distance over land, and may thus reach a watercourse leading them thousands of miles from their original home" (Günther, **97,** 212).

3. A shallow body of salt water between two continents may, by a very slight negative eustatic movement, be drawn off and a dry land connection will be afforded which will enable easy migration for freshwater fishes from one continent to the other. A subsequent positive eustatic movement would conceal the route of migration and one would have to deal with some apparently inexplicable occurrences of identical species.

4. "From the great number of freshwater forms which we see at this present day acclimatised in, gradually acclimatising themselves in, or periodically or sporadically migrating into, the sea, we must conclude that, under certain circumstances, salt water may cease to be an impassable barrier at some period of the existence of freshwater species, and that many of them have passed from one river through salt water into another" (Günther, **97,** 211).

These facts which have been found out in connection with the distribution of freshwater fish of the present are essentially true for those inhabiting the rivers of all earlier continents. They may, furthermore, be considered as equally true for the eurypterids who were highly organized gill-breathers and many of whom were powerful swimmers. While they lacked one of the modes of transportation from the headwaters of one river system to those of another in not having the possibility of accidental portage by birds they had, on the other hand, a far more important means, for they had walking legs, and it is possible that they might have been able to withstand exposure to the air for several hours. In passing from one stream to another their locomotion would be fairly rapid and their migration in this manner might not have been infrequent.

APPLICATION OF PRINCIPLES DEDUCED FROM MODERN FAUNAL DISTRIBUTION[1]

By the discriminating use of the laws which have been observed to be potent in directing the migration of fishes and other organisms living in the rivers at present, and without making any unwarranted assumptions, it seems safe to postulate the following expectabilities in regard to the geological and geographical distribution which we should be able to find among the eurypterids, providing they lived in the rivers.

1. Unless, as some have supposed, but which is very improbable, there were no climatic zones in the Palaeozoic, and conditions of temperature were equable over the whole globe, related or identical species of eurypterids should be found in deposits geographically situated in a circumpolar zone, not necessarily the same as the climatic zones of the present.

2. Eurypterid remains should be expected to occur in deposits of limited areal extent marking lake sediments, flood plain deposits, or littoral deposits in the sea at or near the mouths of rivers.

3. Eurypterids which inhabited the streams of one river system would be more closely related than those living in the tributaries of different and entirely distinct systems, and in general this would mean that forms which lived in the rivers of one continent in any period, would constitute a group of related genera and species, while those living in the rivers of another continent would constitute a distinct group, the individuals of which would be related; and if the different continents should remain unconnected for a long time, geologically, distribution and evolution would continue on each land mass, but we would not expect any of the individuals from one continent to migrate to another, so that succeeding faunas should not show intercontinental affinities, though phylogenetic relations should be discernable on each continent. It must be remembered, however, that remains of faunas from both continents might be carried into basins which received the simultaneous drainage of rivers from each.

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[1] The importance of distinguishing between *dispersal*, the passive and *migration*, the active distribution of organisms has been insisted upon by Grabau (*Principles*, p. 1041).

4. In deposits which, from the study of their lithogenesis can be shown to have come from the same Palaeozoic continents, should be found remains of eurypterids in circumscribed areas as stated in "2" above, and the genera and species, while not necessarily having any near relatives in adjoining deposits, may be identical with forms whose remains are found in a formation perhaps two or three thousand miles distant, but *on the same ancient continent.* Such relationships are to be accounted for by migration from a common source where the headwaters of two or more river systems interlace (see p. 205 above).

5. The distribution of eurypterids would not have had any necessary connection with those organisms living in marine chronofaunas, and consequently, except when eurypterid-bearing deposits merge into thalassigenous ones, or when fragments or stray eurypterids have been washed out to sea, when intercalation between marine deposits would give the age, eurypterids would not serve as good index fossils.

6. Eurypterids would not suffer rapid changes in evolution, since it is a well known fact, that fluviatile types are often persistent for a long period of time. Thus the cray-fish *Cambarus primaevus* Packard of the Green River beds (Eocenic) of Wyoming, is a near relative of the modern *C. affinis* of the same region, a similarity due no doubt to the persistence of the type in essentially the same river basin during the interval.

Zoölogists and palaeontologists who have made detailed studies of the distribution of modern freshwater faunas are thoroughly agreed that accurate results are not to be obtained merely from observations on present distribution. It is an absolute necessity to study the fossil faunas and especially the palæogeography. The reason for this will be evident after a very little thought. If in the Lower Cretacic when there existed the Nearctic continent, comprising most of North America, and continuing across the North Atlantic through Greenland and western Europe, and including the Scandinavian mass, a family of some fluviatile organisms had arisen in the central Canadian area, quickly spreading from one river system to another and finally reaching Europe, we would find in the rocks of that period, that many of the genera on the two modern continents were the same, and that there would be quite a goodly number of identical species. The descendants of these Lower Cretacic organisms would develop on the two continents, (i.e., the two sides of this old nearctic land mass), and the species in the lower reaches of the rivers would diverge in their characters more and more from the parent stock. Those forms which came under the same environmental conditions might, and experience shows that they would develop along parallel lines, appearing in later geological times as similar or even what might be called identical species. In the course of centuries emigrants from an earlier home centre of distribution would pass from the headwaters of one stream to those of another, and soon these forms which had been passing through their individual modifications under one set of environmental factors would migrate down the rivers and mingle with those forms which had in an earlier period sought the lower reaches of the rivers where a different complex of environmental factors obtained, and there the old immigrants and the new, would come to live in the same waters. A single family, in this way, would give rise to a certain number of primitive genera, some of which would migrate far from the original centre of distribution. The descendants of these early immigrants might, after a long time and after having suffered profound morphological changes, return to mingle with the descendants of the provincial forms which had never left the ancestral region. Now let us think of such inter-changes going on across the Nearctic continent all through the Tertiary until at the close Europe was separated from North America by an advance of the sea. At once we have two separate continents and two river faunas. Were one to try to account for the distribution of the fluviatile forms now living in the rivers by a study of the present geography, one would be in despair to account for the similarity or seeming identity of many species on opposite sides of the dividing waters. Evidently the only mode of attack is by the study of successively earlier and earlier fossil faunas and by the slow reconstruction of the palaeogeography for each of those periods. One need not search far to find the application of these hypothetical statements to the eurypterids. If they were river-living organisms then it is clearly impossible to explain their distribution in any particular period without considering their distribution in each immediately preceding period. No one has ever done this because each writer tried to account for eurypterid occurrences on a hypothesis of marine distribution.

The results of migration are very different for marine organisms, because of the fundamental difference between the continuity of the seas and the discontinuity of the lands. Marine faunas, especially the vagrant benthos of the littoral zone and the pelagic ones, tend to be widespread, for they have greater freedom in the size of life districts available, and in the lesser competition, as compared with the lineal extent of rivers and the great struggle for existence, particularly between crustaceous animals. For instance, Ortmann has pointed out that freshwater crayfishes existed in Southeastern Asia, the Malaysian Islands, India, and Madagascar in the Middle Cretacic. In the Upper Cretacic the freshwater crabs (which are geologically younger than the crayfishes) arrived (or originated) in *Lemuria* and "extended into Southern Asia and the Malaysian Archipelago, everywhere exterminating the crayfishes, namely, in India, Southeastern Asia (Farther India and China) and on the islands. They not only acted as a check to the distribution of the crayfishes, but directly annihilated them" (Ortmann **201,** 391). As a result, no crayfishes are today found in the rivers of central and south Asia or on the Malaysian Islands.

We have previously seen that in river faunas the number of individuals is large but the number of genera and species is small, while in marine faunas genera, species, and individuals are abundant. The factor, then, of relative numbers of taxonomic groups would favor marine organisms in widespread migrations. Pelagic and vagrant benthonic organisms, living in the sea, have on the whole rather favorable conditions for migration. With river forms the factors of distribution are more accidental and much depends upon the individual. In the region of interlacing headwaters, streams of different systems are temporarily connected at times of flood and perhaps only two or three individuals of a certain species will change from one system to another, and then, when the connection is broken, the distribution of that species depends entirely upon the ability of the individual to contend with all of the new factors in the environment, and it is pure survival of the fittest which brings about the distribution of that species. In the sea, on the other hand, whole groups migrate or are carried by currents, and the chances are good that a large number or at least enough for populating a new region will survive, whatever vicissitudes befall. Thus, to sum up, distribution of river forms over broad areas is more precarious and fortuitious than is the case with marine organisms.

When we apply such considerations to fossil faunas, to a class of organisms wholly extinct, where we have no facts of modern distribution to help us, no facts of present habitat to point past modes of life, we can see that the criteria which we apply to such fossil faunas in the determination of relationships and migrations must be quite different from the ones applied to marine fossil faunas. We can now understand that a fauna may be made up of individuals which show a fairly close relationship with faunas in neighboring areas, but may contain one species which is identical or nearly so with a species in a fauna three thousand miles distant. If these were marine fossils we could not understand such a thing, because marine faunas show whole groups of species in one region related to groups in another, and contemporaneous marine deposits in the path of migration show similar related groups. But the routes of migration for river forms would almost never be shown to us in the rocks, because rivers in their upper and middle portions degrade and would continually be carrying away the traces of their history which would be recorded only in deltas or flood plains. Thus, contemporaneous and related fluviatile faunas would appear geographically at the outer ends of the spokes of a great wheel which has its hub at the centre of dispersal. The remains of synchronous faunas would of necessity appear scattered over the face of the earth, without any apparent connection; a fact which would be inexplicable if the faunas were interpreted as marine. The only way to solve the problem of the distribution of those forms would be through a study of the palæogeography of the period in which they occurred and of all preceding periods in so far as was possible.

When stratigraphers come fully to appreciate the value of continental deposits and faunas, they will have taken a big step toward the unravelling of the palæogeography of our earth. No one would attempt to restore the conditions of land and sea in the Tertiary without making use of the migrations of mammals and other terrestrial organisms, for it is evident that while a study of marine faunas will show the position of the oceans and epicontinental seas in any period, the exact configurations of the continents, the exact location of land barriers and connections can only be determined by the migrations of the animals and plants living on the land or in the rivers. This applies with as great truth to the Palaeozoic as to the Tertiary, and while the aid of plants cannot there be invoked until the end of the period, I hope to show before concluding this paper that the eurypterids will be of vast service in helping to locate Palaeozoic rivers and routes of migration from one continent to another.

MIGRATION AND DISTRIBUTION OF THE EURYPTERIDS

Theory of Early Marine Habitat and Routes of Migration. As I stated above, the anomalies in the distribution of the eurypterids have not usually been given much consideration, though they are of the utmost importance. There is a current opinion that has somehow been formed about the bionomy of the eurypterid faunas and no one thinks of challenging it. When a eurypterid fauna has been found in a place where a marine fauna was not expected, it has had to be made to fit in with the preconceived opinion about the bionomic facies in which eurypterids are supposed to occur. It has been spoken of as a "most unusual occurrence;" "one which is most interesting because found in beds formerly supposed to be devoid of marine fossils," and so on. Again we read of the clear evidence of a marine passage between the Buffalo region and the Baltic area, because two almost identical species of eurypterids are found in these localities. Formations are declared to be marine because they contain eurypterids, and eurypterids are held to be marine, because they occur in formations considered on *a priori* grounds to be marine. Every writer seems to feel it necessary to fit the eurypterids into a marine or estuarine habitat; where the facts refuse to fall into line, they are cited as ineresting because they fail to, or else they are consciously suppressed or carelessly overlooked. The prevailing opinion as to the bionomy of the successive eurypterid faunas is as follows: Until well on in the Siluric the eurypterids were purely marine forms living in the seas and, inferentially, associated with the marine organisms therein. Toward the middle of the Siluric, the eurypterids all over the world left the seas and migrated into the various brackish water bodies then existing, seeking the mouths of rivers, the bays, lagoons and interior cut-off arms of the sea. From that time until the end of the Palaeozoic, they are supposed to have sought water of ever-decreasing salinity until they became entirely freshwater denizens. Their geographical distribution is accounted for by an assumed migration from one estuary or lagoon to another along the shores of various Palaeozoic continents.

Objections to Marine Habitat Theory. If this succession of events is the correct one, then the following question arises in connection with the distribution: If the eurypterids lived in pools or in marginal lagoons on the seashore, in estuaries, bays or cut-offs how did they get there to begin with?

The question is generally answered by the statement that the eurypterids originally lived in the sea and then migrated to the various marginal water bodies and estuaries where they and a few peculiar crustaceans constituted a brackish water fauna. I have already shown (p. 70) that a "brackish water" fauna consists of modified marine and freshwater euryhaline organisms with a preponderance of marine types, and that the latter show particular characteristics such as dwarfing and thinning of the shell, but that such a fauna has representatives of nearly all invertebrate phyla and is not made up of a single class of organisms. But let us assume for the sake of argument that the eurypterids and a few other arthropods did form a brackish water fauna; then another assumption is necessary, for, if a class of organisms as a whole, such as the eurypterids, should in any given geological period migrate from the sea to estuaries or other brackish water bodies and at the same time should no longer be able to live in the sea, and should not, on the other hand, become adapted to river water, then the remains of such a class of organisms should be restricted to the geological period in which the migration took place, for the class could not persist unless the estuaries persisted from period to period in the same locality (see objection to this on p. 215 below).

But since the class is known to have persisted from period to period, as indicated by the occurrences of their remains in the rocks, we are forced to conclude, on the assumption that the organisms migrated from the sea to the estuaries, that there was a persistent marine stock to repeople each successive estuary. But, if that were true, then eurypterid remains of the same or allied species should be found entombed with the marine organisms of the period in the marine equivalents of the estuarine or other brackish water deposits, and the eurypterids should have constituted a part of the typical marine fauna. But it has been shown again and again that in the contemporaneous marine deposits with typical and undoubted marine faunas, no eurypterids are found, as, for instance, in the marine Wenlock of England, or the marine limestones of the Famennian of Germany. If there is no indication of such a persistent marine stock, then there must have been a persistent stock in the rivers to repeople the estuaries in the successive geologic periods. These arguments may be applied specifically to the Siluric and Devonic of North America. During the Lower Siluric (Niagaran), the eurypterids are supposed to have lived in the sea. During the remainder of the Siluric they are assumed to have lived in or along the shore of a shallow, epicontinental sea having a connection with the Atlantic or other waters to the east. In this restricted sea terrigenous deposits were formed, well represented by the Shawangunk delta. In the pools along shore, where, on account of the more sheltered conditions, only muds were accumulating, the young eurypterids lived. The larvæ were hatched in these pools and the early stages in the ontogeny were passed through, then the mature individuals sought the deeper littoral waters. Thus do Clarke and Ruedemann explain the presence of the abundant fauna composed almost entirely of young individuals in the Shawangunk shales at Otisville, New York, and, during the same period, the closely related but mature individuals in the Pittsford shales at Pittsford, New York.

A comparison, species by species of the forms from the Pittsford and Shawangunk will be given below (p. 225), and it will be seen to show that the two faunas are very closely related, indeed, almost identical except in the size of their individuals, and in the presence, in the Pittsford, of a species of Eurypterus related to a Bertie form to be considered presently. Such similarity might, if taken alone, seem to substantiate the "lagoon" theory. But it is usually impossible to draw very accurate or very far-reaching conclusions from the consideration of faunas or of deposits in a single circumscribed area or at a single horizon; one must take into account the palæogeographic conditions in neighboring regions and finally throughout the whole continent if not, indeed, the whole world, and one must consider the source of supply of sediments, the possibilities of migrations of faunas and the absolute necessity of a fauna to have a medium in which it can live from one period to another, unless we wish to revert to the belief in special creations. Thus, bearing these things in mind, we must account for the origin of the sediments of the Pittsford and Shawangunk and of the succeeding formations, the various waterlimes, which contain eurypterids. It has been demonstrated on pp. 100–6. that the conglomerates and shales of the Shawangunk and the shales of the Pittsford must have come from Appalachia, carried northwards by various rivers.

Now, assuming for the sake of argument that the succession of events during Salina time was that outlined above (p. 212) then the following conditions are implied: (1) The Pittsford and Shawangunk faunas must have constituted the ancestral stock for the Bertie fauna of Erie and Herkimer counties. (2) Throughout the long period from

Pittsford to Bertie time, one or several rivers must have occupied approximately the same position, so that the Pittsford and Shawangunk faunas could escape into the estuaries when the Salina sea became too salt, and could remain there in the brackish water part of the estuary until Bertie time, when they appeared in two localities, at Buffalo, 75 miles west of Pittsford, and around Herkimer, 130 miles east of Pittsford. Taking up the first condition, we are confronted with a grave difficulty if we try to think of the Pittsford and Shawangunk fauna remaining in the Salina "lagoon" or at the mouths of estuaries flowing into that inland body of water during Vernon, Syracuse, and Camillus time, for it is evident that we must consider the Pittsford-Shawangunk eurypterids as the ancestors of those found in the Bertie, if we believe in this estuarine theory. In the succeeding pages, where I shall consider every species of eurypterid as an entity and as a member of a faunule, unless it be an isolated form, and where I shall take up the possible modes and routes of migration of species and of faunas, I shall show that the Pittsford-Shawangunk eurypterids were not the ancestors of the Bertie forms, and therefore the first condition which I mentioned at the beginning of this paragraph as a logical deduction from the "lagoon-estuary" theory is impossible, in which case it would appear that the Bertie eurypterids had no ancestors. Let us suppose, however, for the sake of argument, that the Pittsford-Shawangunk fauna did constitute the ancestral stock for the Bertie fauna and that in the dry and at times uncomfortably saline conditions of Salina time the eurypterids left their lagoon and went into the estuaries and even part way up the rivers, seeking proper salinity of water; then we should look for estuarine deposits of mud or perhaps coarser clastics in the Salina of central and western New York, and for the remains of marine organisms which are characteristic of such deposits. (For criteria of estuarine deposits see p. 77 above.) But we search in vain for estuarine, or delta, or flood-plain deposits in that region. Following upon the Pittsford are the Vernon barren red shales with their evidences of subaërial deposition with thorough oxidation (Grabau, **84, 86a, 87**), and then the Syracuse salt deposits. All of this has been discussed before, and the evidence is clear that there existed no estuaries in the area under question in which the early Siluric eurypterids might have sought refuge. Thus, descendants of early Salina "lagoon" species had no place of retreat during later Salina time, and must have perished of drought, and we see that the Bertie eurypterids were doubly deprived of ancestors if they had to depend upon the Pittsford-Shawangunk fauna.

Theory of River Habitat. To pursue this marine-lagoon theory to its logical conclusions in every case would use up many pages of print and would always lead to absurdities, impossibilities or contradictions. Therefore, without dwelling longer on the perplexities and inconsistencies attendant upon this theory, I shall pass at once to the development and exposition of the theory of river habitat. Throughout the Palæozoic there were in existence in the northern part of the western hemisphere three continents which, though varying much in size from period to period, often becoming confluent and at times even being largely covered by the epicontinental sea, nevertheless preserved a marked degree of integrity. These three continents were (1) *Appalachia*, which occupied what is now the eastern border of North America, and constituted the northward projection of the land mass now known as South America, and which supplied the greater part of the clastic materials deposited in eastern North America throughout the Palæozoic; (2) *Rockymontana*, which lay for the greater part of its length on the present continental mass extending from Mexico to Alaska, a palæocordilleran chain, from which clastic sediments were derived which were deposited on the western border of North America and along the continental shelf; (3) *Atlantica*, the great northern North American and northwestern European continent one portion of which, the Canadian shield, was formerly supposed to have been the source of nearly all of the Palæozoic clastic deposits over what is now the United States. Throughout the Palæozoic this Canadian area was usually connected with the Scottish and Scandinavian masses by a broad strip of land extending across the North Atlantic (see map, fig. 8). There was a fourth and smaller continent, *Mississippia*, occupying the area of the Mississippi valley, which at times was entirely covered by the sea, and again formed a part of Rockymontana. Each of these continents had its own river systems, the organisms living therein being subject to the laws of migration and dispersal which are seen to be operative now. Furthermore, the fluviatile fauna of each continent would be distinct as a rule. If, however, migration in circumpolar belts occurred and fluviatile organisms from one continent passed to another, these migrant forms would yet show their closest affinity not to species living in the rivers of the continent to which they were immigrant, but to those in the rivers of the continent from which they emigrated. In any given period faunas which can be shown to have come from rivers on the same continent should be more closely related than faunas coming from rivers of different continents, but there may be single cases of a family, a genus, or even a species which occurs in sediments from one land mass, which is nearly related to or identical with one in sediments coming from another land mass. In such a case, to determine true relationships one must compare the whole of each fauna, species by species, and must in addition study the ancestors of each fauna and of each species in the preceding periods wherever possible.

THE EURYPTERID FAUNAS CONSIDERED BY CONTINENTS

THE EURYPTERID FAUNAS OF APPALACHIA. Let us turn now to the placing of the various pre-Siluric eurypterids. *Strabops thacheri* from the Cambric is too primitive and morphologically undifferentiated to be looked upon as more than an ancestral form approaching the prototype and from which several branches of the eurypterid tree diverged. The first prolific eurypterid fauna in North America, the first to offer sufficient material and a large enough representation in genera and species to make it possible to state what are the general affinities of the fauna as a whole, is the newly discovered one in the Normanskill shales at Catskill, New York, which has so far been found to contain six species, included in five genera, but undoubtedly many more will be discovered as the material is worked over. On account of the fragmentary nature of the abdomina found, and because the carapaces are usually dissociated from the rest of the body, generic determinations have been provisional and comparisons with related species difficult. Yet the fauna shows a pronounced and altogether surprising similarity to that of the Schenectady beds (Trenton) despite the difference in age. In the case of *Pterygotus*? (*Eusarcus*) *nasutus*, Clarke and Ruedemann "have been unable to distinguish the Schenectady and Normanskill types," (**39**, 412); and have referred a number of carapaces from the Normanskill beds to *P. nasutus*, a species described originally from material from the Schenectady shales. *Eusarcus linguatus* from the Normanskill is very similar to *Pterygotus*? (*Eusarcus*) *nasutus*.[2] *Eurypterus chadwicki*, *Dolichopterus breviceps*, and *Stylonurus modestus* are not well enough represented for relational comparisons to be made, so far as species are concerned. The finding of several Stylonurus carapaces, attached ab-

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[2] Clarke and Ruedemann point out this similarity, but claim also that *E. linguatus* "strongly suggests the *Eusarcus vaningeni*" from the Salina, in position of eyes and shape of carapace (39, 414). A close examination of their descriptions and of all the figures they give does not reveal any marked similarity.

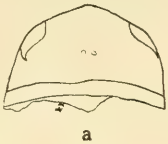
domina, and one with a portion of a leg, so early in the Ordovicic in muds derived from Appalachia is most suggestive. In the succeeding Schenectady beds in the same general region, in muds also washed down from Appalachia, occur a number of specimens which, in the shape of the carapace, position of the eyes, etc., suggest their generic reference to Stylonurus and have been described by Clarke and Ruedemann as *S.*? *limbatus*. They have furthermore found a number of body segments "which have the form and ornamentation of the Otisville species *Stylonurus myops*" (**39,** 296). Although it is a little out of chronological order to bring in the Utica species before taking up the Schenectady fauna, this, nevertheless, is the logical place for its discussion. *Echinognathus clevelandi* was described from a single endognathite which has shown two diagnostic characteristics, namely. an extreme spinosity, and a peculiar and distinctive type of surface sculpture. Clarke and Ruedemann state that this species "was either closely related to Stylonurus or had a convergent development to that genus as far as the two characters mentioned are concerned" (**39,** 322). It may quite properly be asked why it is that if the single endognathite known, shows only two diagnostic characteristics, and these two are recognized as definitive of Stylonurus, the species does not belong to that genus, or at least is it not more than likely, if more specimens are discovered, showing other parts of the body, they will be found to represent Stylonurus? It seems to the author that the geographical and geological position of *E. clevelandi* alone would suggest the greater possibility of the form being a Stylonurus. To be sure, this is somewhat speculative, but it is a suggestion for future work and consideration; it is sufficient that the Utica species is at least closely related to the genus Stylonurus which was found at earlier periods and also in the Siluric and Devonic, always in deposits derived from Appalachia. This statement includes the Utica beds just mentioned, for it is now recognized that, as Professor Grabau first pointed out, the muds were carried down from Appalachia and were merely the eastern near-shore facies which replaced that of the Trenton limestone facies (Grabau, **84,** 231–232). Passing on to the next time in the history of North America when the genus Stylonurus is known to occur, we find *S.* (*Ctenopterus*) *multispinosus* in the Pittsford and two well defined species of this genus, as well as many fragments specifically indescribable though evidently distinct in the Shawangunk, both of which formations have been interpreted on stratigraphic grounds and on a comparison of the two faunas *inter* *se*, but not for any phyletic reasons, as derivatives from Appalachia, the Pittsford constituting the upper part of the Shawangunk (see p. 101 above). The problematic form from the Portage sandstone referred to *S.*? *wrightianus* is too incomplete to be of much value. It probably belongs to Stylonurus; it certainly occurs in an otherwise unfossiliferous deposit which has been interpreted by Grabau as partly of river floodplain and partly of wind-blown perhaps loess-like origin (**87**, 553, 569). Finally, the Upper Devonic yields two species of Stylonurus: one, *S. beecheri* described from a single individual, none too complete, from the Chemung sandstones of Warren, Pennsylvania; the other *S.* (*Ctenopterus*) *excelsior* from two specimens from the Catskill beds of New York and Pennsylvania. This latter species is related in many respects to *S.* (*Ctenopterus*) *cestrotus* from the Shawangunk, both belonging to the same sub-genus. The Catskill is a continental deposit whose material as shown first by Grabau (**86**) and later by Barrell was derived from Appalachia. The specimens of *S. excelsior* were beyond a doubt washed out into the Chemung sea, since all of the species of Stylonurus so far known from North America came from Appalachia, as has just been demonstrated.

Having now followed the history of this one genus from Ordovicic through Devonic time and found that it always lived in the rivers of Appalachia, let us return to the genus Dolichopterus in the Normanskill beds, and trace its subsequent occurrences. As in the case of Stylonurus, the specific relations of the Normanskill form cannot be determined, for only a single small carapace is known, but the point of especial interest is the occurrence thus early of a Dolichopterus. This genus is represented by two species certainly, and one doubtfully, in the succeeding Schenectady beds. Two specimens described under the new species of *D. latifrons* by Clarke and Ruedemann agree "closely with *D. otisius*" from the Shawangunk in the posterior contraction of the carapace (**39**, 270). The carapaces and metastomes of *D. frankfortensis* (Schenectady) do not seem to show close relationship to other species of the genus, though one metastoma "has been found which recalls that of *D. macrochirus*" from the Bertie (**39**, 269). A few fragments having certain Dolichopterus and certain Eurypterus characteristics have been referred to *E.*? (*Dolichopterus*?) *stellatus*, but they are of no value in the present discussion. Thus it is seen that in the meagre, unsatisfactory material from the Normanskill representative of Dolichopterus, one species shows affinities to a Shawangunk form, and one specimen of a second species recalls characteristics of a Bertie species. The evidence is frail, and yet it might seem a little disconcerting to have an individual which came from Appalachia, as we think, showing relationship to one coming from Atlantica, but I shall have a suggestion to make when I come to the Bertie that will do away with even this slight difficulty, which is, after all, entirely negligible, since the only specimen showing relation to a Bertie form is a single metastoma which bears only a suggestion of similarity. Continuing in chronological sequence, the next formation in which a Dolichopterus occurs is the Shawangunk grit where there are two species *D. otisius* with a large representation of carapaces none of which retain more than two body segments, and *D. stylonuroides* of which three carapaces and one more complete individual have been found. The former species has certain characters in common with *D. macrochirus* (Bertie), the young of both being even more alike than the adults. If the two species are phylogenetically related, then the adult *D. macrochirus* has kept the ancestral characteristic of a broad frontal lobe on the carapace, for this is found in the young of both species and retained throughout the ontogeny of the Bertie form, while *D. otisius* in the adult shows a development of this lobe into an angular extension. In this one characteristic, then, *D. macrochirus* would show retardation. The second species in the Shawangunk is rare and shows no close relationship to any known species.

In considering both the Schenectady and Shawangunk faunas, we have seen that there was a species of Dolichopterus in the latter and a single specimen in the former which showed a more or less close relationship to certain species of the same genus in the Bertie. From purely stratigraphic reasoning it is known that specimens of the first two formations were derived from Appalachia, while those of the Bertie came from Atlantica. The question might be raised whether the stratigraphic facts do not conflict with my biological theories, for I have been trying to show that eurypterids found in sediments which were transported by rivers on the same continent should show genetic relationship and should for the most part be distinct from those which lived in rivers on different continents; but the species of Dolichopterus do not seem to conform to this law. In the case of this particular genus with its distribution in time, there would be no apparent physical objection to the accounting for its affinities on the very simple assumption that the Cambric or earlier generic ancestors lived in rivers either on Appalachia or on Atlantica and that during one of the periods when these continents were connected by a strip of land the eurypterids were widely dispersed on both continents; the later consanguinity is thus easily understood. But I think that such an assumption is unnecessary and my reason will be readily apparent when we consider the Bertie species of Dolichopterus, *D. macrochirus*, *D. testudineus* and *D. siluriceps*. The relationship of the first to a species in the Shawangunk has just been discussed. Concerning the second, Clarke and Ruedemann remark: "This species, as represented by the single carapace, is quite similar to *D. otisius*. It differs from the latter mainly by the greater extension of the frontal portion and by the more pronounced posterior contraction of the carapace. The frontal transverse ridge or fold observed in the species is also seen in *D. otisius*" (**39**, 275). If the two species were genetically related, this more pronounced extension of the frontal portion of the carapace would be predicable in the Bertie species, for according to the laws of recapitulation and tachygenesis a morphological character found in the adult of any species will appear at an earlier and earlier stage in the ontogenetic development of its descendants, and since the apparently orthogenetic tendency in the Shawangunk species *D. otisius* showed a progressive modification from rounded to angular and extended frontal margin, the late Bertie species *D. testudineus* should show a more protruding frontal rim than is found in the adult *D. otisius*. The third Bertie species is *D. siluriceps* of which a single poorly preserved carapace is known, and which cannot be compared to any other species save a small form from the Shawangunk. The genus Dolichopterus is not known from any other country, nor has it been found in beds of later age than the Bertie. Even the three species in the Bertie are so poorly represented that one wonders what happened to the fauna. Of the genotype, *D. macrochirus*, four incomplete though excellently preserved specimens are extant; of each of the other two species there is a single carapace. If these eurypterids lived in the Bertie "pools" of authors, it is inconceivable that not more individuals (or exoskeletons) should have been preserved; if they lived in the rivers coming from Atlantica, this scarcity is accounted for. But the study of the phylogeny of this genus leads me to think that Dolichopterus was confined to the rivers of Appalachia throughout its whole racial history. (Its occurrence in so fragmentary a condition in the Bertie suggests that the few remains were transported from the debouchure of some river of Appalachia and carried into the Bertie muds). There is as yet too little evidence, too many pages in the history are still unread, for a reasonably definite conclusion to be drawn, but I think that such a geographical development and confinement more satisfactorily accounts for the facts which are known than any others. We are not obliged to believe that Dolichopterus always lived in the rivers of Appalachia; the facts of distribution and relationship could be accounted for otherwise; but this belief requires fewer special conditions than the assumption of very early dispersal by rivers on the two continents, while a marine habitat is entirely out of the question. One of the strongest reasons for my conclusion that Dolichopterus was restricted to Appalachia lies in the evidence offered by the origin of the sediments. In the study of any problem if the lithogenesis of the formations concerned points overwhelmingly to one and only one history for those formations, then slight palaeontological incongruities should not be accepted as vitiating the history pointed by the facts of lithogenesis; the apparent incongruities can generally be turned into confirmatory bits of evidence if a broad enough knowledge and a scientifically guided imagination can be brought into play. Thus, when the nature of the outcrops, the lithological characteristics of the rocks, and, most important of all, the consideration of possible sources of supply for material, all point to the continent of Appalachia as the region whence the Normanskill, Schenectady, and Shawangunk deposits must have come, while these same considerations point just as conclusively to Atlantica for the Bertie deposits, then, if a fragment of a eurypterid in the Schenectady shales shows a faint similarity to a form in the Bertie, and if half a dozen specimens in the Bertie waterlime bear a slight or even pronounced resemblance to species in the Shawangunk, we must attempt to visualize the conditions obtaining on the North American continent during the early Palaeozoic and we must seek the most rational explanation, the one most in accord with our knowledge of the laws operating at present, to account for these seeming anomalies. And we should never forget that the geological record has revealed but a few specimens of most species of eurypterids, and that sometimes even a genus is described from a single individual, and that when a writer describes a new species he compares it with the ones already known, drawing analogies where he can; but species which may seem to be very much alike when one has, say, a single member, a carapace, or a claw, of each to compare, might, if a large quantity of perfect material were available, be discovered to be so different that kinship would be found to be entirely lacking where formerly it had been confidently pointed out.

From the great mass of detail which it has been necessary to give, we are at length able to reach two conclusions: (1) Stylonurus from its earliest appearance in the Normanskill beds (Black River or Basal Trenton) to its last appearance in the Chemung was an inhabitant of the rivers of Appalachia; (2) Dolichopterus also first known in the Normanskill, but so far not known from beds later than the Bertie, is most rationally to be considered as restricted in its habitat to the rivers of Appalachia, although the paucity and the condition of the specimens make this conclusion not absolutely certain.

This much being determined, we may consider the remaining faunas which have been found in sediments which from other lines of reasoning are recognized as coming from Appalachia. In the Schenectady shales eleven species are recorded, of which four have already been discussed. Of the remaining seven, *Eurypterus ruedemanni* and *E. pristinus* are represented each by a single carapace neither of which is of use in comparisons, and the same may be said of the doubtfully determined form *Euscarcus* (?) *longiceps* of which a few incomplete carapaces are known. Nine carapaces of *Eusarcus triangulatus* have been found, and these Clarke and Ruedemann state "have in common the broad, short, subtriangular form; and the forward position of the marginal lateral eyes bears a close resemblance to the carapace of *E. scorpionis* from the Bertie waterlime" (**39,** 258). Yet the figures, measurements and descriptions of these two species given by the above mentioned authors do not bear out this "close resemblance." In reference to *E. triangulatus* they say that the carapace is "twice as broad as long (length of type, 20 mm., width 43 mm.)" and of *E. scorpionis* they say that the carapace is about "as broad as long" (p. 234), while in the measurements which they give of this species the length is to the width (in millimeters) as 18: 22, 60: 66, and 56: 59, respectively. For comparison I give outline drawings of the restoration of the carapace of *E. scorpionis* and of the actual carapace of the type of *E. triangulatus* (Figs. 19a and b). One of the commonest species in the Schenectady shales is *Hughmilleria magna*, known from a number of carapaces, some abdomina, and a half complete individual. "This exhibits a form of the preabdomen corresponding to *H. socialis*," but the swimming leg is "relatively longer than that of *H. socialis*" (Pittsford) (**39,** 342). Several detached body rings have been found regarding which Clarke and Ruedemann say: they "exhibit a type of ornamentation, consisting of transverse lines near the anterior margin, known to us only in *H. shawangunk*, the Otisville representative of the genus" (p. 342). Thus the nearest affinities of this Schenectady species are to forms from the Pittsford and Shawangunk, which it has been suggested might themselves be merely growth stages and not "species." Only comparatively young (for the most part nepionic or neanic) individuals are known from the Shawangunk, but it is significant that many of these are almost identical in form of the carapace and the position of the eyes with larger, neanic or ephebic individuals from the Schenectady, indicating relationship by this recapitulation of characteristics in ontogeny (see fig. 20.) The two remaining species of the Schenectady fauna, *Pterygotus* (*Eusarcus*?) *nasutus* and *P. prolificus* are unlike any other species known from this country, so that their comparative value is small. Although the last mentioned species is the most profuse in the Schenectady beds, yet the variability in the shape of the carapaces is so great that one might easily be led astray in drawing conclusions. On the whole, the study of this fauna reveals it to be rather unsatisfactory. For one thing, it is made up for the most part only of carapaces and these are often fragmentary; besides, the forms are so distinctive, possessing such unique and specialized characteristics, that with our present



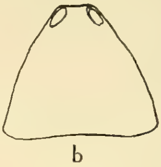
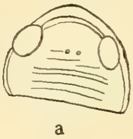


Fig. 19a. *Eusarcus triangulatus.* Clarke and Ruedemann. × ½.
(After Cl. & R. 1912, pl. LXXXIV, fig. 7)
Fig. 19b. *Eusarcus scorpionis.* Grote and Pitt. × ½.
(Outline after Cl. & R. 1912, pl. XXVII, fig. 1, restoration)



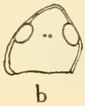


Fig. 20a. *Hughmilleria shawangunk* Clarke. Nepionic Individual. × 8.
(After Cl. & R. 1912, pl. LXIV, fig. 2)
Fig. 20b. *Hughmilleria magna* Clarke and Ruedemann. × ½.
(After Cl. & R. 1912, pl. LXXXV, fig. 11)

slight knowledge of the various faunas we are unable to perceive relationships which very possibly exist. Two species, however, do show kinship with known forms. *Hughmilleria magna* has characters in common with *H. socialis* and *H. shawangunk* from the Pittsford and Shawangunk, respectively, while *Dolichopterus latifrons* agrees "closely with *D. otisius* from the Shawangunk in the posterior contraction of the carapace." Thus, whatever relationship is indicated between the species of the Schenectady fauna and those of later faunas, is to species in the Pittsford and Shawangunk, all three of which formations have elsewhwere been shown to have had their origin in the sediments from Appalachia. Once again, it appears that rivers coming from the same continent have successive faunas more closely related than those from diverse continents.

Comparison of Pittsford and Shawangunk Faunas. The study of the lithogenesis of these two formations has shown that the Pittsford shale is of the same age as the shales in the upper part of the Shawangunk (p. 101 above), for which reason it is fitting to consider the faunas of the two formations at the same time, especially since the sediments are known to have come from Appalachia in both cases. A comparison of the Pittsford and Shawangunk faunas shows that the two most common species, *Hughmilleria socialis* from the former and *H. shawangunk* from the latter are almost identical. In the shape of the body and form of the head the two species closely resemble each other, while the telsons of the two are identical. As one reads through the description of the Shawangunk form he is struck with the constant similarities in the anatomy between this and the Pittsford species. For instance, Clarke and Ruedemann say in regard to *H. shawangunk:* "The metastoma has not been seen well preserved in position, but we refer several metastomas to this species because they possess on the one hand, the form of that in *H. socialis*, and on the other, exhibit a peculiar, striated ornamentation apparently characteristic of *H. shawangunk*" (**39**, 345). Again, "The crawling legs appear to have been both short and slender as in *H. socialis*" (**39**, 344). Because of these similarities, it seems not improbable that *H. socialis* might represent a mature *H. shawangunk*, especially since no specimen longer than 8 cm. is known from the Shawangunk, and no specimen so short as that from the Pittsford, where the individuals are up to 15 cm. in length.

Of the other five species in the Pittsford, *Pterygotus monroensis* is of small importance for it is represented by a single carapace and two fragments. The carapace looks as though it might well belong to a large Hughmilleria; at any rate it has no close affinities to any other species. Similarly, little of correlative value can be deduced from *Stylonurus multispinosus* which is known only from a group of endognathites. In their characteristics they are different from anything in the Bertie (**39,** 297), and are of little relational value.

It will be shown below (p. 232) that *E. pittsfordensis* is closely related to *E. lacustris* in the Bertie, but as will be seen, this is entirely expectable.

In the Shawangunk fauna the most abundant species is *Hughmilleria shawangunk* whose relationship has been discussed under the Pittsford fauna. The very rare forms, *Eusarcus* (?) *cicerops*, *Dolichopterus stylonuroides*, *Stylonurus myops*, and *Pterygotus globiceps*, represented by only a few fragments, show no particular relation to species in any other fauna. Indeed, a comparison of the young of *E. scorpionis* with the young of *E. cicerops* shows that the cephalon was very different in outline and the position of the eyes was not at all similar (Clarke and R., **39**). Similarly, *Stylonurus cestrotus*, found only in a fragmentary condition, "stands apart from all its allies in a number of characters that show it to be an aberrant form" (**39,** 291) *Eurypterus maria*, of which many young and one or two mature individuals have been found, is "greatly different from all its American congeners," (**39,** 190). The relations of *Dolichopterus otisius* have already been pointed out, and it has been shown that while it agrees in certain characteristics with one species, in others it agrees with a different one, so that its affinities cannot be said to be with any particular fauna.

Summarizing the evidence offered in a comparison, species by species, it becomes clear that the dominant, most abundant species in the Pittsford and Shawangunk faunas are alike and that there is only one form in either of these which shows relationship to a Bertie species.

Summary of Facts of Distribution on Continent of Appalachia. The following points may be briefly recapitulated: 1. In the sediments which it has been demonstrated (by myself or others), were with more or less certainty derived from Appalachia, the eurypterids are either unique, showing no relation to known species in North America or other continents, or else they show phyletic relationship *inter se*, the species of later faunas having certain characteristics in common with those of (generally the mature forms of) earlier faunas.

2. Three genera, Stylonurus, Echinognathus, and Hughmilleria were restricted to the rivers of Appalachia.

A far greater interest must attach to the vast northeastern continent of Atlantica which stretched across the north Atlantic and formed a land bridge of vital importance in the migration of the eurypterids. The organisms living in the rivers of this continent were not geographically restricted like those in the rivers of Appalachia, whose remains were washed out occasionally into the surrounding ocean waters, but which were prevented from migration to European fresh waters by the broad expanse of the Palæozoic Atlantic; more fortunate by far were the fluviatile inhabitants of Atlantica, for this continent, we may feel sure, was fairly permanent throughout the Palæozoic, even though the ocean at times encroached over much of the southern part; it was the northern portion that would be vital for the interlocking headwaters of different river systems, and as we shall see there is overwhelmingly convincing evidence pointing to such an intimate relation between the river systems of the periods from the Upper Siluric through the Devonic. Not only were the geographical position and extent of Atlantica more favorable for the widespread dispersion of the eurypterids than were the same physical features of Appalachia, but the sediments derived from the former continent were for the most part of the particular lithological character most favorable to the preservation of organic remains, while those from Appalachia were quite often coarser, being prevailingly sandstones and conglomerates, with only thin beds of intercalated muds. The early differentiation in the character of the clastic deposits from these two continents reflects the still earlier difference which had existed between them in the matter of elevation, for, whereas during Ordovicic and Lower Siluric (Niagaran) time the Canadian area, already peneplaned, had been largely covered by the sea, as indicated by the remnants of Niagaran limestones, and whereas during the same period the Baltic region and that area now forming the southern shore of the Gulf of Finland had likewise been covered by a shallow sea in which coral reefs flourished, the continent of Appalachia on the contrary, had jutted up from the Atlantic with lofty mountain ranges of crystalline rocks. Thus it came about that the rivers in their slow but efficient work of denudation brought into the waters bordering the continent of Atlantica sediments that were calcareous and usually fine-grained (waterlimes) while the rivers of Appalachia carried highly siliceous materials of medium or coarse grain (sandstones and conglomerates) and the winds transported siliceous sands.

THE EURYPTERID FAUNAS OF ATLANTICA. The eurypterid-bearing formations which, mainly on lithological grounds, are thought to have come from Atlantica are (1) Bertie, (2) Rondout, (3) Manlius (4) Siluric waterlimes of Oesel, (5) Waterlimes of Gotland, (6) Wenlock of Scotland, (7) Old Red sandstone. The faunas of these various formations will be taken up in detail with a view to determining the relations between individual species and between the faunas *inter se*.

Of the above mentioned formations and their contained faunas, the first three, which are North American, are quickly disposed of. The Rondout waterlime has thus far yielded but a single species, and this is the same as one from the Bertie, namely, *Eurypterus remipes*. Similarly, only one species is known from the Manlius, a number of specimens, for the most part poorly preserved, having been found in various localities ranging from Albany, Herkimer, Madison and Onondaga counties, New York, to Put-in-Bay, Lake Erie, where it occurs in the stratigraphically older early Monroe beds. Only one specimen has been found in which the abdomen is preserved, the remaining occurrences being only of carapaces, and even these are often poorly preserved. In outline of carapace and lack of ornamentation thereon, this species more closely resembles *E. brewsteri* from the Arbroath paving stones than any form known from North America, though the similarity to *E. lacustris* from the Bertie is not to be overlooked. Thus, the only known eurypterid from the Rondout is the same as a species from the Bertie, and the single species from the Manlius and the lower Monroe shows affinities to one from the Bertie and to one from the Old Red sandstone. With these two so easily dismissed, we may turn to a detailed discussion of the Bertie fauna in which connection it will be necessasy to establish the complete affinities of each species by a detailed morphological and phylogenetic comparison with species in preceding and contemporaneous faunules in America and Europe; the centres of dispersion and the routes of migration must be carefully studied, and the possibilities of fluviatile and marine distribution must be weighed. More deductions can be drawn from the study of the Upper Siluric faunas than from that of any other, because of the abundant data available, the appearance of chronofaunas in widely separated localities and the relative abundance of individuals and species in several of the faunules. Because it is impossible to draw correct deductions regarding the mode of distribution of organisms in any one period from the observation of the distribution visible at that time (see p. 208 above), and since the truth is to be arrived at *only* by the consideration of former land and sea connections or barriers, it is necessary in discussing the Bertie faunule to take into account the palæogeography of preceding periods and the distribution of earlier faunas.

It has seldom been our good fortune to find two succeeding eurypterid faunas in the same locality, so that not many opportunities have been available to trace direct descent; but New York State has been favored in this respect and too much importance can not be attached to the relational values of the Pittsford, Shawangunk, and Bertie faunas.

Comparison of the Pittsford, Shawangunk, and Bertie faunas. As a matter of fact, the Bertie fauna in neither "pool" shows any very marked affinities with the Shawangunk fauna or with the Pittsford, with one exception, already noted, and more fully discussed, below. Of the fourteen species known from the Bertie, there are only four in which even a slight resemblance can be seen to the upper Niagaran forms, and this resemblance in each case (with the one exception noted) is so very small that it cannot be said to constitute a proof of genetic relationship. For instance, *Dolichopterus* (?) *testudineus* from the Herkimer "pool" is represented by a single uncompressed carapace which in outline, general proportions, and the position of the eyes is quite similar to one of the specimens of *D. otisius* in the Shawangunk. But while this general resemblance to one carapace of the Shawangunk form has been pointed out by Clarke and Ruedemann, attention should also be called to the fact that it is very different from one of the best preserved, most typical Shawangunk carapaces of the same species. The sub-elliptical shape of *D. testudineus* is quite distinct from the sub-quadrate one of *D. otisius*, and it does not seem to the author that any genetic relation is indicated between these two forms. To overcome this difficulty of lack of relationship between the Shawangunk and Bertie faunas, it might be argued that the latter was derived from the Pittsford alone. But the only species in the latter which is supposed to have even a semblance of relationship to a Bertie species is *Pterygotus monroensis* which has been compared with *P. cobbi.* The former species was founded on a single carapace, and two other fragments are now known. One of these is the fragment of a free pincer of the chelicera which is thought to belong to *P. monroensis.* This shows one long, rounded tooth at the extremity, then a short tooth, another long tooth but not so long as the first, four short teeth alternating in size, followed by a long tooth, then three shorter ones. The chela of *P. cobbi* from the Bertie shows three long teeth at the end, two short ones, a long one nearly as long as the one at the extremity, then three fairly short ones followed by another long one. The teeth in the chelae in these specimens are similar neither in size nor arrangement, so that no particular relationship is set up between *Pterygotus monroensis* and *P. cobbi* (Fig. 21 a and b).

Not only, then, do the species themselves offer no indication that the Bertie fauna was derived from the Pittsford alone, but, furthermore, it seems impossible to believe that the five Pittsford species included in four genera should give rise to the profuse Bertie fauna of fourteen species included in four genera, two of which are different. The four Pittsford genera are: Eurypterus, Pterygotus, Eusarcus, and Dolichopterus. Clearly, with the exception of *E. pittsfordensis* which will be considered presently, the Pittsford-Shawangunk fauna does not supply the ancestors for the Bertie fauna which is thus left without progenitors on the basis of the "lagoon-estuarine" theory usually advanced. There is also another difficulty. Stylonurus has representatives in North America in the Pittsford and in the Devonic and Carbonic, but none existed in the Bertie waters which should, according to the generally accepted views, have been the one place for the perpetuation of the race of the eurypterids in the late Siluric.

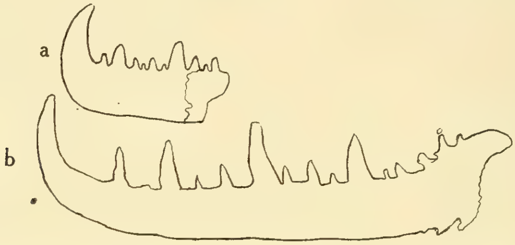


FIG. 21A. *Pterygotus monroensis* SARLE. FRAGMENT OF FREE CHELA. × ½. (After Cl. & R. 1912, pl. LXX, fig. 3)

FIG. 21B. *Pterygotus cobbi* HALL. FREE CHELA OF CHELICERA. × ½. (After Grote & Pitt. 1878, fig. p. 301)

There is yet one other difficulty arising if the Pittsford-Shawangunk fauna was ancestral to the Bertie. How can the many points of similarity between certain Bertie and European species be accounted for? It has already been pointed out that *Eurypterus remipes* from the Herkimer region is so closely related to *E. fischeri* of the

Baltic area that the latter for a long time was identified with the former. Schmidt was the first to suggest that the differences between the two species were only geographical variations arising through migration. With this idea Clarke and Ruedemann have concurred. In fact, they point out in many places the close similarity between the Bertie and Oesel fauna, and especially between the two commonest species in both, *E. remipes* and *E. fischeri.* Now, if the Bertie fauna was an estuarine one, preserved from Pittsford time in various brackish water bodies, when and how did migrations take place to the Baltic sea of the Upper Siluric? The answer will undoubtedly be that the members of the marine stock in the Lower Siluric which were not caught or did not voluntarily seek refuge in the "lagoon" or remnant of Niagaran sea in New York State, migrated along the shore of Atlantica, passing from estuary to estuary until they reached the island of Oesel. This might seem like a very happy solution, if the British Isles did not intervene between America and Oesel, and if they did not have a very clear record to show that no such migration took place. In the discussion of the faunas of the various Palæozoic continents, given below, it will be shown that the Wenlock, Ludlow, and Lanarkian faunas of Great Britain offer no indications of migrations along the neritic zone during those periods and that in many cases new genera as well as new species arose suddenly without, apparently, having a genetic relationship to corresponding taxonomic units in other countries.

Since the assumption that the early Salina eurypterids lived in a "lagoon more or less cut off from the sea," leads to such difficulties, we must seek another theory. Let us assume that they lived in the rivers, and draw the logical deductions. It has been shown from their lithogenesis that the Pittsford and Shawangunk deposits must have been derived from Appalachia, while the Bertie was derived from Atlantica. Rivers, whether existing at the same time or at different geological periods, would carry related forms if coming from the same continent, but unrelated or only distantly related forms if coming from two different continents. Thus the Pittsford and Shawangunk eurypterids would be near relatives to say the least; while the fact that the larval forms from the latter are merely the young of those from the former is all the more according to our expectations.[3] Likewise the absence of close relationship between the Shawangunk and the Bertie, and with one exception between the latter and the Pittsford, is easily understood and entirely to be expected. The baffling break in the phylogenetic history of Stylonurus is also explained. First found in the Pittsford, it came from Appalachia; on that continent its evolution continued through the remainder of Siluric time, its remains not being found because the continental, chiefly river flood-plain, deposits from Appalachia during the Upper Siluric and the Lower Devonic are unknown on the North American continent. The perplexities which were so detrimental to the "lagoon" theory are completely removed by the river theory. But if the latter be accepted, a new objection arises—only one, to be sure, yet at first it seems to demolish the theory altogether. How does it come to pass that *E. pittsfordensis* so closely resembles *E. lacustris* as to seem almost certainly the direct ancestor? In specimens approximately the same size the two species are found to be almost identical in the proportions of the cephalon (i.e., length: width = 2 : 3), and in the position and shape of the eyes. On the other hand, the posterior portion of the cephalon flares out in *E. pittsfordensis* or at least broadens out in a hyperbolic curve, while *E. lacustris* is marked by the nearly parallel sides of the cephalon. *E. lacustris* is not so broad a species as *E. pittsfordensis*, but otherwise does not differ especially in form. The telson in the latter species is unusually long, being nearly equal in length to the rest of the postabdomen.

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[3] It should be noted here that the adult individuals of the Shawangunk were preserved only as unrecognized fragments, the young forms alone, by virtue of their small size, escaping the destruction which was meted out to their progenitors, as was discussed on p. 101.

An immature, but complete individual in the Buffalo Society of Natural Sciences Museum measures as follows:[4]

	mm
Length of head	21
Length of body	68
Length of telson	57
Total length	146

In another specimen which is incomplete, the telson measures 11.5 cm., while in *E. lacustris*, in an individual of about the same size, it measures only 6.5 cm. In spite of these differences, however, the species are very much alike, though not so closely related as *E. lacustris*, *E. remipes*, and *E. fischeri*, which can be understood from the fact that the three latter belong to the same horizon, while the former precedes them by a long period. I am quite prepared to agree with Clarke and Ruedemann that *E. pittsfordensis* is the ancestor of the Bertie forms. Not only this; it actually came from the same region as the later types. For it must be apparent that the rivers of Atlantica, which furnished the deposits of the Bertie, were also in existence during Pittsford time and must have mouthed into whatever remnant there was of the Niagaran sea. It is not particularly likely that the ancestors, if so we may call them, of the Upper Siluric rivers occupied precisely the same location as the Bertie or Herkimer rivers, but undoubtedly they existed in somewhat the same general region. Therefore, what is more likely than that during Pittsford time these southward-flowing rivers from the continent of Atlantica should bring down the remains of organisms living in them? These rivers could not themselves have supplied the muds of the Pittsford shales, for they came from a limestone region, and whatever sediments they carried must have been of the nature of waterlimes. If such calcareous deposits were spread out on the flood plains of those rivers they are now no longer visible, for subsequent erosion has removed all traces of deposits of Pittsford age in Canada; but there is where a eurypterid fauna would be expected to occur, just as in Bertie time when waterlimes were deposited farther south the fine eurypterid fauna is found. This explanation makes it entirely clear why *E. pittsfordensis* is related to no form yet known from the Shawangunk, but has characteristics showing that it was ancestral to forms in the Bertie. New discoveries have corroborated this theory.

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[4] These measurements were kindly furnished to me by Mr. Henry R. Howland.

Professor C. J. Sarle has discovered the Pittsford fauna at a new locality in New York State. The details of this have not yet been published, but it is known that both *Eurypterus pittsfordensis* and Hughmilleria are common. The rock is a gray shale and the material was undoubtedly supplied by the rivers of Appalachia. Since Hughmilleria is otherwise known only from deposits derived from Appalachia it is reasonable to assume that the same rivers which carried in the muds also brought in the Hughmilleria. The abundance of *E. pittsfordensis* is not surprising, for if the rivers from Atlantica emptied into the Pittsford basin there is no reason why they should not bring as abundant a fauna as did those from Appalachia. If, as is to be expected, the basin in which these deposits were laid down was at times a fresh water lake, the eurypterid faunas of both river systems may have met and lived for a time in this water body. They were then killed by the sudden incursion of the Guelph sea which brought with it the remnant of the Guelph fauna found in the intercalated limestone.

Further corroboration is offered by Van Ingen's discovery in Oneida county already referred to. In the concretionary block obtained from that locality and determined from lingulas and orbiculoideas in it to come from dark gray shales with intercalated waterlimes and dolomite beds 21 feet below the base of the red Vernon shale,[5] were found three carapaces and fragments of a eurypterid, which Clarke and Ruedemann have named *Eusarcus vaningeni.* They state that "the outline of the body . . . . the visual surface . . . . the appendages, so far as seen, are like those of *E. scorpionis.* The tergites and sternites have the form and relative dimensions of *E. scorpionis.* . . . . The ornamentation is that of *E. scorpionis*, but the scales are smaller and more clearly arranged" (**39**, 420, 421). It is also somewhat related to *E. cicerops* from the Shawangunk, but the relation is generic rather than specific. That this species of Eusarcus, more closely related to a species in the Bertie than to a contemporary species in the Pittsford, should be found in the waterlime facies of the Pittsford rocks in a region but a few miles distant from the mouth of the subsequent Herkimer river, is a most unusual corroboration of our theory. It is exactly what could have been prophesied. How such an occurrence is to be explained on the lagoon theory is puzzling.

If the river hypothesis is the correct one it must account for the migration of the eurypterids from the Buffalo region to the Baltic during the Salinan or early Monroan. If we assume the existence of two rivers flowing from the rather low and flat limestone-covered country to the north, into a sea which had its shore extending through New York, as indicated on the map (fig. 8), it would not be difficult to understand that the shed exoskeletons of arthropods inhabiting the waters of these rivers and occasionally dead or even living individuals would be carried down stream, and become embedded in the fine lime sediment of the two neighboring deltas or in the interstream areas. Probably the eurypterids themselves were seldom carried down to the debouchures, since it is their molted exoskeletons which are generally found. To account for the similarity of the Buffalo and Herkimer faunules, it is necessary to postulate the interfingering of the headwaters of the Bertie and Herkimer rivers. The physical and faunal conditions would then be analogous to those existing at the present time in the Columbia and Missouri rivers, as outlined on

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[5] I shall refer to these shales hereafter as the Farmer's Mills shales, from the locality near which they were found.

p. 205 above. If we assume such a mode of distribution by rivers for the eurypterids, it would explain the close relationship which exists between forms isolated, but in neighboring localities; that is, *Eurypterus lacustris* of the Buffalo area, and *E. remipes* of the Herkimer area, nearly related species, but occurring in two isolated localities. But besides, these two occurrences, the river hypothesis must account for the close relation of both of these species to the one in the Baltic region (see below p. 235). There is good stratigraphic reason for believing that in Siluric time there was a continental mass (the Atlantica of Grabau), which as already outlined occupied much of the present North Atlantic and extended from northern North America entirely across to eastern Europe. According to Walther, several high mountain chains extended across this land connection (**294**, 251), and undoubtedly large rivers came down from these. Their headwaters would very probably interlace, as do those of all large rivers on the various continents at present.

Under such conditions we can see that the common ancestor of *Eurypterus lacustris*, *E. remipes* and *E. fischeri* could have lived in the headwaters of one of those rivers, and that getting farther away from the point of origin, the various species derived from it would be differentiated. *E. lacustris* and *E. remipes* were developed in two neighboring streams, but the forms connecting *E. remipes* and *E. fischeri* which must have lived in the rivers of Atlantica, are now buried under the waters of the North Atlantic Ocean. The more distant relationship of these species suggests that there were intermediate forms, though these have not yet been found, and are probably nowhere preserved, though it is not impossible that Siluric strata with such intermediate species may exist beneath the ice cap of Southern Greenland. In this great system of rivers, which to all appearances characterized the continent of Atlantica, the Bertie and Herkimer Rivers were not very far apart, so that the faunules of each were very similar. In fact, the deltas spread out at the mouths of the two rivers may have become confluent in their outermost or seaward portions, though the waterlime now known would, as above explained, represent only the inshore facies. It may have happened that in times of flood the river waters flowed out over a broader area near the debouchures until some of the distributaries became for a time confluent, thus allowing some of the species from one river to be carried over into the area of deposition of the other. Thus might the presence of *Pterygotus cobbi* in both regions be accounted for.

The Upper Siluric Faunas of the Baltic Region. Let us next consider the fauna from Oesel, Gotland, and the Baltic provinces of Russia. On Oesel three species and two varieties of eurypterids are known: *Eurypterus fischeri* Eichwald, *E. fischeri* var. *rectangularis* Schmidt, *E. laticeps* Schmidt, *Pterygotus osiliensis*,[6] Schmidt, and *P. osiliensis* var. *laticauda* Schmidt. From Gotland the same Pterygotus species is reported, but no Eurypterus has yet been found. In Podolia a few specimens of *Eurypterus fischeri*, fragments of *Pterygotus osiliensis* occur, and Schmidt reports a few broken pieces of shell referable to the latter species in Galicia. From Livland, *Pt. osiliensis* has been reported by Eichwald. It is thus seen that in the Baltic Isles and West Russian provinces three species and two varieties of eurypterids occur. The close similarity, approaching identity, of *Eurypterus fischeri* to *E. remipes* and *E. lacustris* from the Bertie has been dwelt on at length (p. 230 above); the variety *E. fischeri rectangularis* naturally has its closest affinities with the Bertie forms. Schmidt described *E. laticeps* from two carapaces and did not compare it with any other form. There is no species in the Siluric fauna of Great Britain to which it shows any relationship, and so far as I am aware it cannot be compared with any other European form; but it shows considerable resemblance to *E. microphthalmus* from the Manlius waterlime. The largest specimen of the latter species measures 30 mm. long by 45 mm. wide, while one of the two known carapaces of *E. laticeps* shows corresponding measurements of 40 mm. and 60 mm., the ratio in both cases being as 2 to 3. The form of the eyes corresponds quite closely in the two species, but whereas in *E. microphthalmus* the distance between the eyes is almost equal to that between the eye and the lateral margin, in *E. laticeps*, on the other hand, the eyes are more widely spaced so that the distance between the eyes is one and a half times as great as between each eye and the margin (Schmidt, **248,** 63). No ornamentation has been observed on the carapace of *E. microphthalmus*, but on *E. laticeps* a series of black dots occur in rather regular arrangement between the eyes, extending forward toward the frontal margin and posteriorly a shorter distance. Since both of these species are as yet so little known, it is not safe to draw conclusions as to their relations. The fact of chief interest is that the Baltic form is more closely related to the Manlius species than to any other. There remain the specimens of *Pterygotus osiliensis* and its variety, *laticauda.*

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[6] While it is not the intention of the author of this paper to revise or emend any generic or specific appellations of other authors except in so far as is necessary in the discussion of the problem at hand, it is advisable to call attention to the fact that *Pterygotus osiliensis* belongs to the subgenus Erettopterus established by Huxley and Salter for the Pterygoti which have bilobed telsons.

In the lower beds of the Old Red sandstone are two species of Pterygotus, *bilobus* and *anglicus* to both of which *P. osiliensis* shows some similarity, though the stronger affinity is to the latter of the two from Great Britain. A comparison of Schmidt's restoration of *P. osiliensis* and of an actual specimen of *P. bilobus* var. *inornatus* (fig. 22), brings out the similarity in general form, the correspondence of the telsons especially in their bilobate character, the agreement between the pincers and the arrangement of teeth in the chelae, the similarity in the shape of the carapace and in the size and form of the swimming paddles. The abdomen of *P. bilobus* is not so narrow nor so gracefully tapering as is that of *P. osiliensis;* the proportions of the carapace likewise differ, that of the former species being longer than

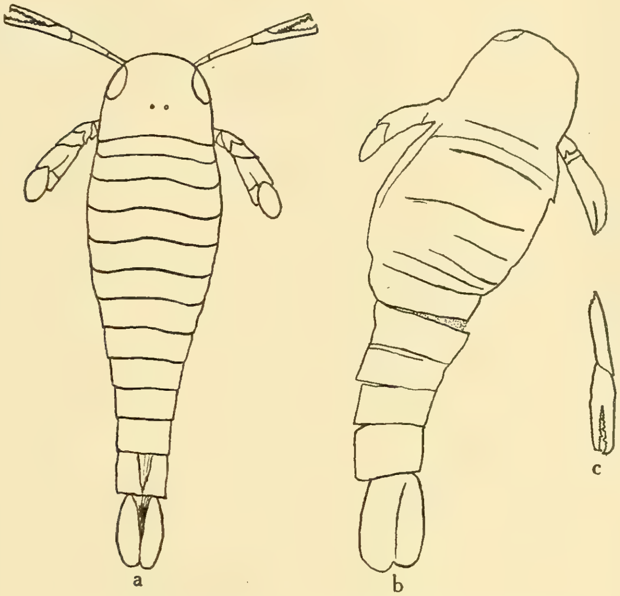

Fig. 22a. *Pteryogotus osiliensis* Schmidt. Restoration
(After Schmidt. 1883, p. 72, fig. 1 A)
Fig. 22b. *Pterygotus bilobus* var. *inornatus* (Salter). × ½.
(After H. Woodward. 1878, pl. X, fig. 1)
Fig. 22c. Chela of Same Species. × ½.
(Ibid. fig. 2)

that of the latter. The similarities, however, are pronounced, and it is not to be denied that *P. osiliensis* finds its nearest relative in *P. bilobus.* Aside from this species, there are several others belonging to the subgenus Erettopterus, and we cannot dismiss our comparative study without calling attention to them. They are: *Pterygotus* (*Erettopterus*) *grandis*, and *globiceps* from North America; but they are so very distinct from the Baltic form that genetic relationship is in no way indicated.

The variety *laticauda* of *P. osiliensis* is founded not without certain misgivings on the part of Schmidt for an exceptionally large metastoma and a similarly large telson found associated with the *P. osiliensis* specimens. So far as the present problem of the determination of the relations between faunas is concerned, this variety would be classed along with *P. osiliensis*, and needs no separate discussion.[7]

The species of faunas of the Upper Siluric waterlimes of Oesel, Gotland, Livland, Podolia, and Galicia are thus seen to show very close relationship either to species in the Bertie waterlime, as in the case of *Eurypterus fischeri*, and var. *rectangularis*, or to species found in Great Britain at the end of the Siluric or the beginning of the Devonic. That is, they show affinities to the faunas occurring in deposits which for reasons other than faunal ones were judged to have been derived from the continent of Atlantica.

The Fauna of the Wenlock. There now remains only the discussion of the eurypterid-bearing deposits of Great Britain, (6) the Wenlock of Scotland, and (7) the Old Red sandstone. In the Wenlock beds there is a large fauna represented by at least twelve determinable species of eurypterids, and one would expect to be able to attain to some critical knowledge of the relationship of the forms there occurring to those in North America and Europe; but while the fauna lacks not in the number of species and of individual remains, complete or even nearly complete specimens are not to be found, and one is forced to attempt to draw conclusions concerning relationships from fragments of legs, carapaces, or body segments, an attempt which is not only difficult but altogether unsatisfactory because of the probable errors attending it. Let us, however, consider the species

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[7] The author, however, questions the propriety of the creation of a new variety for the two specimens found. Undoubtedly the metastoma which Schmidt cites is larger than the two which he considers belong to the typical *P. osiliensis;* on the other hand, it is only slightly larger than would be required to fit with the operculum or with the thoracic segment which he figures on Plate V, figs. 1 and 3. The three metastoma are so similar in form and ornamentation that it seems rather dangerous to use mere variation in size, particularly when that is so expectable, and when various parts of the body indicate a species of no mean dimensions.

seriatim, bearing in mind that details in structure are in most cases unavailable and that consequently genetic relationships are obscured. Of the genus Stylonurus, three species have been described by Laurie: *S. elegans*, *S. macrophthalmus*, and *S. ornatus*. The first species has been placed by Clarke and Ruedemann into the subgenus Ctenopterus, together with *S. cestrotus* Clarke, and *S. multispinosus* Clarke and Ruedemann; the former from the Shawangunk, the latter from the Pittsford, the subgeneric characters being the relatively greater length of the second and third pairs of legs when compared to the first, and the presence on the former of more than two pairs of long, slightly curved spines, which are vertical on the lower side of the segments (Clarke and Ruedemann, **39,** 286–287). The Scottish species is so different from the two American forms grouped with it that the author is tempted to take exception to their being placed in the same subgenus, particularly because the very characteristics which are mentioned as diagnostic are not always observable. My reasons for objecting to the subgeneric grouping of this form under *Ctenopterus* are as follows: (1) It is unsafe to base a taxonomic group of such great value as a subgenus upon the characteristics of one set of organs alone, as for instance, the legs. Nothing at all is known of the body of *S. multispinosus* and very little about that of *S. elegans;* only that of *S. cestrotus* having been found in good enough preservation to allow of restoration. (2) Single identical morphological characters do not of themselves establish specific relationship and, therefore *a fortiori* they cannot be used to unite their possessors into groups of higher taxonomic value for it is a law of palaeontology which is coming more and more to be recognized, that the same morphological characters crop out in many diverse phyletic groups and their presence in no wise indicates genetic relation. Thus, a modification in the proportions of the legs or in the number of spines cannot be considered characters of subgeneric rank. (3) The length, breadth, general form and grouping of the spines on the second aud third pairs of legs are not at all similar in *S. elegans* and *S. cestrotus* (fig. 23). The comparatively short spines of about equal length, regularly spaced, and projecting at almost right angles from the walking legs, in *S. excelsior* (provided the restoration of this species is correct) and in *S. cestrotus*, together with the greater length in the second and third pairs of legs as compared with the first pair, might allow of these two species being placed in the same subgenus, and with them quite probably *S. multispinosus*. *S. elegans*, however, is too distinct, it seems to me, to be considered even subgenerically related, while specifically this species must certainly stand alone. This is especially evident when we consider (4) That one of the two diagnostic characters of the subgenus Ctenopterus depends upon the comparison of the lengths of the first three pairs of legs, the particular comparison being made between the first, and the second and third pairs, but in *S. elegans* the first pair is unknown.

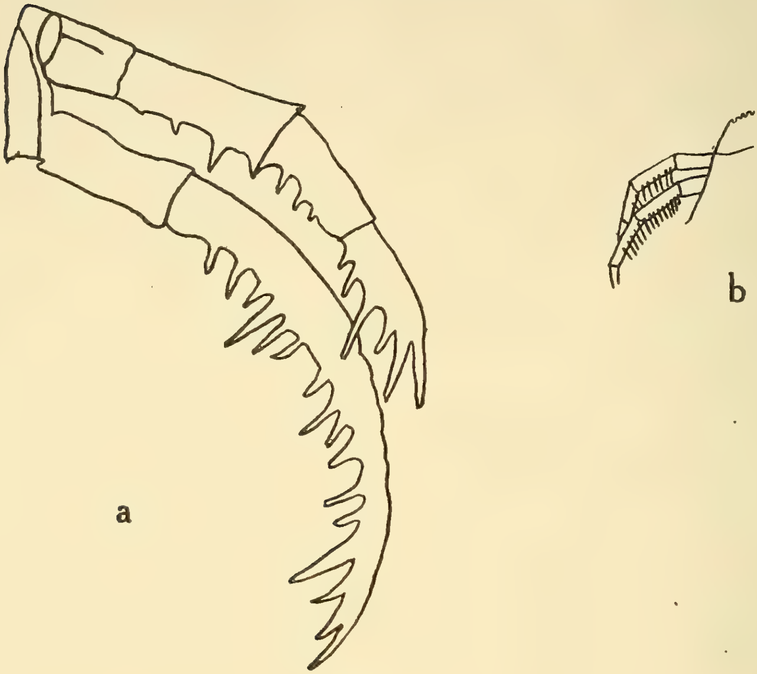

FIG. 23

a. Stylonurus elegans Laurie. Second and third legs on right side. (After Laurie, 1900, pl. II, fig. 12.)

b. Stylonurus cestrotus Clarke. Second and third legs on left side. (After Clarke and Ruedemann, 1912, pl. XLIX, fig. 4.)

Stylonurus ornatus and *S. macrophthalmus* are in some respects quite closely related to species occurring in the later Scottish horizons in connection with which they will be spoken of again. Here it is sufficient to note that there are no North American species which have the characters of the genus Stylonurus (sens. str.) namely, the first three pairs of legs relatively short and stout, with only two short, curved spines on each segment, as in Drepanopterus and Eurypterus.

From the Wenlock, Laurie has also described three species of Eurypterus: *E. conicus, E. minor* and *E. cyclophthalmus.* These are three small species which are not very well represented and which are primitive or retarded in development. They are not related to any American forms nor do they appear to fill ancestral positions, for the British species of the Upper Siluric and Devonic. In some one characteristic a Wenlock species seems to foreshadow a later one, but phyletic lines are difficult, if not impossible, to trace. The exceedingly large eyes in the single known specimen of *E. cyclophthalmus,* and in *E. conicus,* and the small size as well as the general form suggest that these two species are larval forms. Clarke and Ruedemann consider that *E. minor* also is either immature or has had its development arrested. They think that such is especially the case in *Bembicosoma pomphicus* Laurie, a small, stunted form with large head, rapidly tapering body, and "warty texture of skin."

The genus Drepanopterus Laurie is now placed by Clarke and Ruedemann as a subgenus of Stylonurus. To this group belong Laurie's three species: *D. bembicoides, D. lobatus,* and *D. pentlandicus,* which need not be discussed in detail since they show no affinities either to American or to continental European forms. The species described by Laurie as *Eurypterus scoticus* has since been revised by Clarke and Ruedemann who recognized its affinities to Eusarcus. In the American faunas it finds its nearest representative in *E. scorpionis* from the Bertie. Because of the impossibility of making accurate measurements of the proportions of different parts of the bodies and of obtaining exact outlines to show the form, one is unable to make careful comparisons.

The only remaining species in the Wenlock eurypterid fauna is *Slimonia dubia* Laurie, a small individual, much broken and without appendages. Laurie has included in this species a second individual which shows a portion of the telson. Since the genus at present comprises only two species, the one just mentioned, and *S. acuminata* from the Ludlow, there is no opportunity to trace relationships over broad areas. The main reasons for making a new species of the Wenlock Slimonia, were, the difference in geologic age between the two forms, and the fact that the Pentland Hills individual was gradually tapering instead of abruptly contracted in the seventh segment into a telson.

Summary of the Wenlock Fauna. A survey of the entire eurypterid fauna of the Wenlock of Scotland must be made with the realization beforehand that all of the material is so fragmental, dismembered, macerated, and poorly preserved that detailed descriptions, accurate measurements, and unimpeachable determinations are things beyond the power of anyone to obtain, and that, furthermore, until discoveries of new faunas at earlier horizons in Great Britain shall be made, the ancestry of the Wenlock species must remain obscure. Many new genera appear suddenly in this Lower Siluric horizon, and we are unable to do more than say that such and such genera came from a common ancestor. It is unfortunate, indeed, that the Ordovicic of Great Britain has not yielded such faunas as it has in America. Yet, keeping these points in mind, we are still struck by the provincial character of the Wenlock fauna. There is not a species in it which is closely related to any of the North American species except *Eusarcus scoticus* which foreshadows in certain respects *E. scorpionis* from the Bertie.

The Fauna of the Ludlow. The Ludlow of Lanarkshire has yielded nine species of eurypterids. *Slimonia acuminata* Salter has just been mentioned in connection with *S. dubia*, the two being very similar. *S. acuminata*, Clarke and Ruedemann state, "has all the features of a local and aberrant type," (**39,** 130). *Pterygotus* (*Erettopterus*) *bilobus* with the four varieties: *acidens*, *crassus*, *inornatus*, and *perornatus* is found abundantly at Lesmahagow, the last variety, however, being very rare. As was pointed out in the discussion of the Baltic provinces faunas, there is closer relationship between *P. bilobus inornatus* and *P. osiliensis* than there is between either of these forms and a species in any other fauna (p. 238 above). *Stylonurus logani* belongs to the revised Stylonurus *sens. strict.*, having the second and third pairs of legs short, thick, and with two pairs of spines in each segment (see Woodward, **312,** 131). There are no known species on any other continent to be compared to this form which is not even very much like any of the Wenlock species, with two of which it agrees in its subgeneric characters, but with neither of which it has specific similarities. Indeed, it is quite unlike *S. macrophthalmus* which is characterized by the peculiar ear-shaped epimeral expansions, the long parallel-sided metastoma, the rounded cephalon, and very short second pair of legs. It is a little more like *S. ornatus* which has a slightly more squarish cephalon than *S. macrophthalmus*, and which has not such pronounced ears on the epimera, although these are extended posteriorly to a much more pronounced degree, than in *S. logani.*

The only species which has epimera approaching in size and form those of *S. macrophthalmus* is *S. scoticus* from the Old Red sandstone (see p. 251 below), from which, however, it differs in certain important features. It is closest to a second species found in the Old Red sandstone, *S. powriei*, which it resembles in the tapering form of the body the long, narrow telson, the subquadrate outline of the head (this is decidedly square in *logani*) and in the great length of the fourth appendage. In details, on the other hand, these two species differ considerably, so that *S. logani* must remain a rather separated species until new discoveries reveal its relatives. It is of great interest to have reported from the Ludlow fish bed in one of the tributaries of Greenock Water (see p. 164 above), *Stylonurus ornatus* associated with the typical Lanarkian (Downtonian) fishes and with *Eurypterus dolichoschelus*, a Ludlow and Lanarkian species, together with Ceratiocaris, Dictyocaris, plants, etc. (p. 164 above). *S. ornatus*, then, evidently persisted from Wenlock into and through Ludlow time. In this case one is again confronted with an anomalous geographic and geologic distribution. The Pentland Hills are less than thirty miles distant from the Lanarkian inliers, and the two areas are approximately on the same line of strike. In two thin beds but a few inches in thickness and extending only a few yards laterally *S. ornatus* occurs in the Wenlock in Lanarkshire; but in the Pentland Hills this species occurs in none of the many Ludlow eurypterid horizons until the fish bed is reached and there a few specimens are found. If the eurypterids lived in the Wenlock sea as they are commonly supposed to have done, then the supporters of this view must account for the limited vertical and horizontal distribution of the merostome remains, since it is absolutely inconceivable that members of a marine neritic fauna should be confined to an area a few square yards in extent. It is equally inconceivable that a marine fauna should be perpetuated for so great a period of time as from the Wenlock through the Ludlow, the members of the later fauna in some cases showing resemblance to members in the earlier, while in others they are entirely distinct and apparently arise suddenly, there being, besides, no indications of a persistent marine stock to furnish decendants from the Wenlock fauna, nor yet any trace in the marine Ludlow of the incursion from other regions of new genera and species of eurypterids. Moreover, we can not understand why one species of the Wenlock recurs in the Upper Ludlow, but does not occur in the beds of intermediate age, although there are many such with good marine molluscan faunas and even with fragments of other eurypterid species. Such a perpetuation, to repeat, would be impossible if the eurypterids were not having a continuous existence in the sea. But their remains are at all times spasmodic in appearance, being altogether wanting in certain horizons, especially where the typical marine fauna is abundant. The fact that they occur in a given band which, when traced even a short distance laterally, shows no lithological change, but only an absence of eurypterids, indicates that migrations along shore were non-existent; while the fact that new species and even new genera appear at horizons far separated from underlying and overlying eurypterid horizons seems to deprive "marine" eurypterids of ancestors or descendants, while to account for a marine *Stylonurus ornatus* in the Wenlock of Lanarkshire and in the uppermost Ludlow of the Pentland Hills, is not within the inventive powers of the author. But, on the other hand, the conditions of bionomy in rivers are eminently satisfactory to account not only for the persistence of a species for a long period of time without morphological modifications of specific rank, but also for the development of new species and genera, and for their sudden appearance. This takes place, because they have been developing either in other river systems, whence they have migrated to the headwaters of the river at the mouth of which their remains are found, or because they have been traversing a great distance in longitude, automatically suffering specific variation in their progress. In this way, would I account for the anomalies in distribution just dwelt upon (see also p. 203 et seq.).

Of this Ludlow fauna there still remain four species to be considered. There are three species of Eusarcus which may be taken up at the same time: *E. scorpioides*, *E. obesus*, and *E. raniceps*. The last species may be quickly dismissed, since it is represented by a single specimen showing only the carapace and a part of the abdomen, enough, indeed, to place the individual generically; but specific comparisons are impossible. *E. scorpioides* is represented by one almost entire individual, a large, robust form in many respects similar to *E. scorpionis* from the Bertie waterlime. The length and width of the appendages, the number and disposition of spines thereon, the ratio of length of carapace to the remainder of the body, and the proportions generally agree in the two species. Even more like *E. scorpionis* is the single known specimen of *E. obesus* from the same Lesmahagow horizon, and it has been suggested by Woodward, who described the species, that *E. obesus* may possibly represent the young of *E. scorpioides;* certainly *E. obesus* looks very much like a young individual of *E. scorpionis* figured by Clarke and Ruedemann from the Bertie (Figs. 24 and 25). Thus there is close relationship between the two species from Lanarkshire and the one from the Bertie.

The last species from the Ludlow fauna, and the only Eurypterus yet found therein is *E. lanceolatus* Salter. As Sarle, Clarke, and Ruedemann have pointed out, this species has many points in common with Hughmilleria and either belongs to that genus or is transitional to it. The form of the body, shape of the carapace and of the telson, marginal position of the eyes, the relative proportions of the somites, and details in the appendages, all point to affinities with *Hughmilleria socialis* Sarle, from the Pittsford (figs. 26, 27). Such a relationship seems a little disconcerting at first, in view of the fact that the Pittsford sediments and fauna came from Appalachia, while the Ludlow was a derivative from Atlantica and should have a fauna essentially distinct from the former. Indeed, with the exception of this one species, the members of the Ludlow fauna show no relationship to any species from the faunas of Appalachia. We have here, as a matter of fact, one of the "anomalies" of distribution

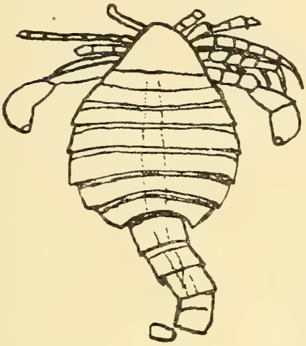

FIG. 24. *Eurypterus obesus* H. WOODWARD. $\times \frac{9}{10}$
(After Woodw. 1878, pl. XXX, fig. 8)

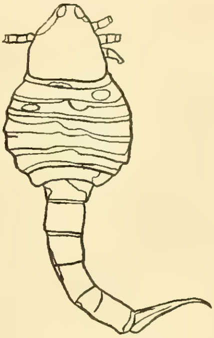

FIG. 25. YOUNG OF *Eusarcus scorpionis* GROTE AND PITT. $\times \frac{1}{2}$
(After C. & R. 1912, pl. XXXVI, fig. 1)

which may occur among fluviatile organisms, but are inexplicable for marine forms. In the upper Niagaran in North America *H. socialis* occurs by the hundred in the Pittsford shale and the closely related *H. shawangunk*, which may be only the young of the former species, occurs in the synchronous shales of the Shawangunk, but in no other part of the world at that time, so far as we know, were there any representatives of Hughmilleria. It appears that the genus originated in the rivers of Appalachia. Curiously enough, in the Upper Ludlow, that is, lower Upper Siluric, of Scotland, *Eurypterus lanceolatus* appears, showing a striking resemblance to *Hughmilleria socialis.* The prolific Scottish fauna of the Wenlock has revealed no possible ancestors for this distinctive Eurypterus (or Hughmilleria?) and one naturally wonders how it arose. Since Hughmilleria was restricted in occurrence in the Niagaran, any migrations which took place must have been effected during the Salina period. The important Salina

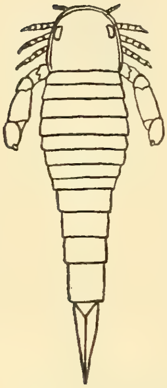

FIG. 26. *Eurypterus lanceolatus* SALTER. × ½. (After Woodw. 1878, p. 142, fig. 44)

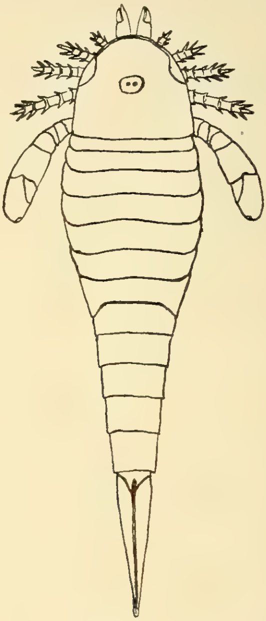

FIG. 27. *Hughmilleria socialis* SARLE × ½. (After Cl. & R. 1912, pl. LIX, fig. 1)

break or period of emergence has recently been recognized by Grabau as affecting all countries bordering on the North Atlantic and has been recorded for North America, Scotland, Oesel (by the author), and even in what was formerly supposed to be the continuous section in England (**89B**). There was a widespread diastrophic movement at the end of the Niagaran marking a broad expansion of continental areas during Salina time so that perhaps nowhere are there preserved to us the marine sediments of that period. Certainly the North American eurypterids were cut off from marine routes of migration with which most authors like to provide them, and yet migration seems to have gone on. The Salina in North America was a period of aridity west of the mountain mass of Appalachia, but that chain died out northward and probably merged into the continent of Atlantica, there being no northeast Atlantic sea-lobe at that time. Several possible lines of fluviatile migration were open and nothing is more probable than that emigrants from Appalachian north and northeast flowing rivers should have entered some one of the tributaries of the systems on Atlantica. The exact mode of transit can not be determined, but many routes were open. Indeed, it is possible that migration occurred even in Pittsford time from the rivers of Appalachia into one of the Pre-Bertie rivers which we have seen probably existed in the western New York region even during the Niagaran (p. 113 above). This much we may conclude: There were many routes and possibilities of migration open to eurypterids living in the rivers of Appalachia during the Lower and Middle Siluric, but continuous marine paths to Europe were non-existent. Furthermore, the distinctness of the Ludlow fauna as a whole from any of the faunas of Appalachia, but the close relationship of *one species* from the former to two from the latter is inexplicable for members of a marine fauna, but normal and expectable for members of fluviatile faunas.

The Old Red Sandstone Fauna. The last of the European formations which is believed to have been derived from the continent of Atlantica is the Old Red sandstone. Most the eurypterids occur in the beds in various localities in Forfarshire. By far the most abundant species is *Pterygotus anglicus* which finds it nearest relatives in *Pterygotus buffaloensis* and *P. macrophthalmus* from the Bertie, and *P. osiliensis* from the Baltic region. The various points of similarity are so well known that it is not necessary to take them up. *Pterygotus minor* is a small form found associated with *P. anglicus*, but it is a unique form, and shows a marked divergence from congeneric forms throughout the world. The telson is elongate, spatulate, with a pronounced median keel, which is represented on the last three segments of the postabdomen as a long spine, rather than a ridge (Woodward, **312,** 199, Pl. X, fig. 2; 195, p. 35, Pl. I, fig. 4). There can be little doubt that this species, which is represented by a single, nearly entire individual, represents a neanic stage of some form, the adult of which probably is not known. Only two and a half inches long, it has the large eyes slightly removed from the border, a feature which is so characteristic of neanic Pterygoti; but it is difficult to account for the pronounced spines on the body segments, and for the high keel, features, which in associated species are less developed at so early a stage. The shape of the carapace and the position of the eyes suggest *P. macrophthalmus* from the Bertie, but the spines on the epimera of the last five segments of the postabdomen, the median spine on the last three, the very marked median keel on the telson as well as the proportions of the telson indicate a specialization far beyond that observable in the species just mentioned, particularly when it is borne in mind that all of these features are observed in an undoubtedly young individual, which means that they would be much more marked in maturity. This species has all of the appearances of an aberrant form, the relations of which it is impossible to determine from the one known specimen, but it certainly has characters which unite it with Bertie species and with forms which occur in the Baltic region.

The Stylonuridæ of the Old Red sandstone are represented by four species: *S. scoticus*, *S. powriei*, *S. ensiformis*, and *S. symondsii*. The first, represented only by a head and by one nearly entire individual, is yet so remarkable, so entirely distinct from the typical Stylonurus that it has been set apart by Clarke and Ruedemann as the representative of a new subgenus, Tarsopterus. These two authors have dwelt upon what they consider the close similarity between *S. scoticus* and *S. myops* from the Shawangunk, stating that "it seems probable, therefore, that *S. myops*, when fully known, will prove a representative of the subgenus Tarsopterus of which *S. scoticus* is the type" (**39,** 303). The reasons which they cite are: occurrence of "spurlike epimera of equal relative size," the "outline of carapace," and "the approximate position of the eyes and the sculpture of the tergites." Since it is my purpose in the present section of this paper to marshal all of the evidence provided by the relationship existing between the genera and species of different faunas in order to determine from which continents these were derived, it is evident that a claim of close similarity between a species in the Shawangunk fauna, derived as I believe from Appalachia, and a species in the Old Red sandstone derived from the continent of Atlantica, as I hope to prove, must be carefully investigated. Therefore, I proceed to the points enumerated, always bearing in mind that certain types of similarity are of more value than others. In the beginning I may state that *S. myops* is known only from immature specimens, most of which are carapaces alone, and that only one entire specimen has been found and this is but 55 mm. in length (see pl. 52, fig. 6, Clarke and Ruedemann). The largest carapace of *S. myops* observed measured 19 mm. in length by 27 mm. in width; the only carapace of *S. scoticus* known measured 16 cm. in length and 19 cm. in width; the single, entire individual known measured 3 feet, 4 inches in length. A most profound difficulty arises at once, namely, that of comparing neanic and nepionic specimens of a mid-Siluric species with a gerontic, or perhaps a late ephebic individual of the Lower Devonic. But granting that such comparisons are possible or even allowable, let us turn to the characters which would justify placing these two species in the same subgenus. First, there is the outline of the carapace. It must be admitted even by Clarke and Ruedemann that, with all due allowance for compression, the carapaces of *S. myops* display a most unusual amount of variation in outline, some, were it not for the position of the eyes, being easily referable to Eurypterus. The carapaces show a strong tendency to grow narrower posteriorly, showing the greatest width in the anterior third, whence the lateral margins slope gently backwards; the nearly parallel sides shown in the carapace of *S. scoticus* are usually not present in *S. myops*, while the frontal

SPECIES	LENGTH OF CARAPACE IN MM.	BREADTH OF CARAPACE	RATIO: LENGTH: BREADTH
S. myops, smallest carapace observed	3.5	5.5	0.63
S. myops, type	12.3	16.5	0.74
S. myops, largest carapace observed	19.0	27.0	0.70
S. macrophthalmus (Ludlow)	51.0	61.0	0.83
S. powriei	50.0	62.0	0.80
S. scoticus (separate carapace)	160.0	190.0	0.84
S. scoticus (carapace attached to body)	204.0	242.2	0.83

margin is quite as likely to be curved as to be nearly flat (as in *S. scoticus*). A comparison of the proportions of length to breadth of carapace in these two species and in two others with which relationship might more readily be established will, when taken in connection with the illustrations, show that *S. scoticus* in so far as its carapace is concerned, is far more nearly related to associated forms in the Old Red and to others in the Ludlow, than to the Shawangunk forms.

From these figures we may conclude that Clarke and Ruedemann find the approximate ratio of length to breadth of carapace in *S. myops* to be as 2 : 3, but it is evident that in *S. scoticus* it is 4 : 5. It is not to be denied that the ratio changes from that in the young of *S. myops* where it is 2 : 3 to that in the type where it is nearly 3:4, and perhaps it might be conceded that in larger forms the ratio might approach 4 : 5; but we cannot be sure. There is in the Ludlow, however, a species which has a carapace proportioned exactly as in *S. scoticus* and even in the Old Red is a species, *S. powriei*, with proportions almost the same. Thus there is no need to form conjectures about what might be possible relations to a Middle Siluric species from Appalachia when there are forms which actually show the similarity in formations derived from the same land-mass.

A second point of supposed similarity between *S. scoticus* and *S. myops* was the occurrence of long and pronounced epimera in both species. I have in another part of this paper discussed the significance of spinous prolongations on the epimera, but I shall call attention to the arguments again, since they are not universally recognized. Beecher has assembled a wealth of illustration from all branches of the animal kingdom to show that the appearance of spines as a modification of any morphological character marks degeneration in respect to that character, and, when extreme spinosity is accompanied by certain other easily recognizable and similarly degenerate characters the species, genus or family, all members of which show like degeneration, is doomed to decline and extinction. But not only that; as Beecher, Hyatt, and a few present-day palaeontologists, notably Grabau, have shown and have demonstrated by countless illustrations which have led to the most certain deductions, the formation of spines is a homeomorphic character, not in the least indicative of genetic relationship in forms which develop such spines, but marking only an onto- or phylogenetic stage. Spines may and do appear in end-members of totally distinct phyletic groups and are of absolutely no diagnostic value in determining true relations. The Eurypteridae offer many new illustrations of this law which is so simple, which so strongly makes its appeal to the reason, and which yet is so constantly ignored. The Carbonic species of Eurypterus develop spines wherever possible; the surface scales are produced into pointed wedges or spines; the ends of the epimera grow out to a great length; spines develop on the appendages not only in rows along the various segments but also on the lines of junction between segments: showing that the final expression of morphological characters in the eurypterids was the development of spines which was followed by extinction. Such a development has seemed expectable to many authors for the species living in the late Palæozoic, in the Mississippic, and Carbonic; but there is really nothing to prevent these phylogerontic characters from appearing much earlier. And so, to apply all of these general statements to the case in question, I would say that the epimeral spines observable on *S. myops* indicate that the line which that species represented was on the decline even in the Siluric, at a time when the majority of eurypterids were at their acme. A glance at the illustration of *S. scoticus* (Woodward **312,** Pl. XXII) will show to the reader that this species has a typically gerontic appearance. Its epimeral prolongations do not in the least resemble those in *S. myops*, but are most like those of *S. macrophthalmus* from the Ludlow.

Two points remain as supposedly indicative of relation between these two species. The position of the eyes is, it seems to the author, the only feature of marked similarity, but certain of the British forms also show such a position, so that it is not of striking importance. As for the ornamentation of the tergites, I can see little to warrant the statement that the sculpture is similar in the two species.

The species *Stylonurus* (*Tarsopterus*) *scoticus* has now been compared in detail with *S. myops* and it has been shown that they are not closely related and consequently the presence of the first genus in the Old Red sandstone not only does not militate against my thesis that the faunas living in rivers coming from the same continent and in the same latitude should be most alike, but it is actually an additional proof, for *S. scoticus* is most nearly related to Ludlow and Old Red species, though it shows phylogerontic characteristics which somewhat obscure its relations.

The three remaining species of Stylonurus from the Old Red may be quickly dismissed. *S. symondsii,* from England, is represented by a single apparently complete carapace which is almost as long as wide, but is distinctly narrower posteriorly than anteriorly. There is a possibility that the marginal fold has been destroyed in the posterior portions, but Woodward thinks that the specimen is entire, and that the fold did not pass all the way around the carapace. *S. ensiformis* is described from a single broken tail spine which, it seems to the author, is hardly sufficient for the founding of a new species, and certainly is of no use in determining the affinities of the fauna. *S. powriei*, represented by a single individual, has a carapace very similar in form and identical in proportions to *S. scoticus*, from which species it differs most noticeably in having the last pair of appendages long and tapering, not short and broad. Woodward has suggested that it probably had epimeral prolongations which have not been preserved, because only the internal mold in sandstone has been found, and the epimera would be likely to remain with the actual integuments; for the same reason none of the surface markings are visible. The tail is extremely long and narrow, quite similar to the telson of *S. logani* from the Ludlow, which form it also resembles in the character of the last pair of appendages. Both species belong to the provisional group of Stylonurus s. st. recognized by Clarke and Ruedemann.

Completing the Old Red sandstone fauna are two species of Eurypterus: *E. brewsteri* and *E. pygmaeus*. The first consists of a carapace, a portion of a thoracic segment slightly displaced, and an ovisac containing more than twenty ova (Woodward, **312,** 151). Woodward says that "this species agrees most nearly in general form with *E. lacustris*" from the Bertie, while Clarke and Ruedemann have pointed out a close similarity to *E. microphthalmus* from the same horizon (**39,** 195). But since both authors make their comparison on the form, proportions of length or width, and position of eyes, and since the actual figures do not support either statement, I find it impossible to agree with them.

	LENGTH OF CARAPACE	WIDTH	RATIO L:W
	mm		
Eurypterus brewsteri	1.48	5.52	0.27
E. lacustris	44.00	63.00	0.70
E. microphthalmus, type	15.50	22.00	0.70
E. microphthalmus, best preserved specimen	17.5	27.40	0.64

E. pygmaeus is a small form found near Kington, England, and though represented by very young individuals, yet has characters which point to its affinities with *E. remipes* (Fig. 28).

SUMMARY OF FACTS OF DISTRIBUTION ON CONTINENT OF ATLANTICA. We are now enabled to bring together all of the many lines which we have been following in tracing the affinities of the faunas which for other reasons were supposed to have come from the continent of Atlantica, and here, as in the case of the faunas of Appalachia, the great weight of evidence shows that the Bertie, Rondout, Manlius, Ludlow, Lanarkian, Baltic, and Old Red faunas are more closely related inter se than they are to the faunas which from the study of the petrogenesis of the formations in which they occur, were believed to have come from other continents.

THE EURYPTERID FAUNAS OF MISSISSIPPIA. So far only a single fauna is known from the continent of Mississippia, and therefore it is not possible to institute any comparisons between the species found in that fauna and those from other faunas on the same continent, as was possible in the case of Atlantica and Appalachia; the most that can be expected is that we shall find the Kokomo eurypterids distinct from all those which lived in rivers on other continents. As we shall see, the theoretical expectations are fully borne out by the facts.

FIG. 28. *Eurypterus pygmaeus* SALTER. × 1
(After Woodw. 1878, pl. XXVIII, fig. 5)

The Eurypterid fauna of the Kokomo waterlime is distinct from any of the known North American eurypterid faunas. The material is never well preserved and the number both of species and of individuals is small. "*Stylonurus* (*Drepanopterus*) *longicaudus*," says Clarke and Ruedemann, "is a unique form among the American eurypterids being the sole representative thus far found on this continent of this rare and phylo-genetically interesting genus. From its Scottish allies, it is readily distinguished by its slender and elongated postabdomen and the long, clavate telson." (**39**, 320) Four specimens are known, two young and two mature individuals, and though they are in sufficiently good condition to enable Clarke and Ruedemann to make a restoration of the species, they do not approach the perfection of preservation found in the Bertie material. The characters are clearly enough shown to make it a certainty that this form has no relatives in the American faunas, so far known. Five specimens of *Eusarcus newlini* are known. This species, though attaining the gigantic size of *E. scorpionis* of the Bertie, shows marked differences in the proportions of the body. There is a general shortening up and broadening throughout. A set of figures taken from Clarke and Ruedemann's discussion will bring out this fact; some of the figures are only approximate.

Lengths in millimeters

	CARAPACE	PREABDOMEN	POSTABDOMEN	LAST POST ABDOMINAL SEGMENT	TELSON	RATIO OF CARAPACE TO REST OF BODY
E. scorpionis	53	67	146	40	62	0.17 : 1
E. newlini	58	57	112	34	43	0.23 : 1

It will be noted from these figures that although *E. newlini*, in the specimen measured, had a carapace 5 mm. longer than that of *E. scorpionis* the remainder of the figures for the other portions of the body are considerably less, showing that the proportions throughout are different. The ratio of the length of the carapace to the length of the rest of the body in the two species shows that in *E. scorpionis* it is as 0.17 : 1, while in *E. newlini* it is as 0.23 : 1. The cephalothoracic appendages are much stouter in *E. newlini*, with longer and stouter spines. Since the Bertie and Kokomo species of Eusarcus are the only ones in this country which are well enough preserved to allow of careful description, they are the only ones which can be compared and it has been shown that they do not show close relationship. The Kokomo fauna has yielded further two species of Eurypterus which are very similar, namely, *E.* (*Onychopterus*) *kokomoënsis*, and *E. ranilarva*. Of the difference between these two species Clarke and Ruedemann say: "It is possible that these differences are only those of sex, a point that at present cannot be determined since the opercular appendages of *E. ranilarva* are not distinctly shown" (**39**, 211). The proportions between the length and width of the cephalon in the Kokomo and Bertie forms are quite different. In *E. ranilarva* the ratio is as 7.1 : 10; in one specimen of *E. kokomoënsis* it is as 8 : 10, in another as 8.4 : 10, but in *E. dekayi* the ratio is only as 6 : 10 in one specimen and is even as low as 5.3 : 10 in another.

From these figures it appears that the Kokomo forms had cephala which were much more nearly square than rectangular. A set of comparative figures for the proportions in the different parts of the three species brings out the differences clearly.

Lengths in millimeters

SPECIES	CARAPACE	PREABDOMEN	POSTABDOMEN	TELSON	RATIO OF CARAPACE TO REST OF BODY
E. dekayi	31	40.4	56.0	53.0	20.7 : 100
E. ranilarva	35	40.0	50.0	35.0	27.8 : 100
	33	43.5	41.5	36.0	27.0 : 100
E. kokomoensis	28	32.3	43.4	30.4	25.9 : 100

The same relations hold here between the body proportions of the Kokomo and Bertie species as held in the case of Eusarcus. A comparison of the figures for *E. dekayi* and the first specimen of *E. ranilarva* shows that though the carapace of the latter is longer, all of the other parts of the body are shorter. Thus, the Eurypterus species as well as the one of Eusarcus are relatively shorter and broader forms than the ones found in the Bertie.

The Kokomo eurypterid fauna as a whole is quite distinct from any other American fauna, a fact which is difficult to explain on the theory of marine habitat for these organisms. If, as Clarke and Ruedemann have stated, the Kokomo is of Lockport age, and belongs to the marine fauna of that time, it is greatly to be wondered at that there should be no eurypterid fauna in the succeeding Guelph beds in the same locality or in adjoining regions. Yet the only Guelph form that has ever been found is the single specimen of *Eurypterus* (*Tylopterus*) *boylei* from Ontario, a form which shows not the slightest resemblance to any of the Kokomo eurypterids. If the Kokomo is to be considered of Monroan age, for reasons which have been given in full on p. 118 then, on the marine theory, the Kokomo forms should show relationship to the Bertie, and their area of deposition should constitute merely another "pool" cut off from the Monroan sea. But it has just been shown that the Kokomo fauna is quite distinct from the Bertie and that the two faunas have no species in common, a fact difficult to explain on the ground that the forms lived in neighboring "pools" where faunas were segregated from a once widespread marine fauna.

On the other hand, these peculiarities are easily understood, if we consider the eurypterids as fluviatile organisms. It is quite evident that the Kokomo deposits have a distinctly different source from those of the Bertie. If then, these eurypterids belong to a distinct river system, developed upon a separate land mass, it would indeed be surprising if they were not wholly distinct specifically from those of the rivers of Atlantica which were responsible for the Bertie waterlime deposits. The alternation of beds with marine fossils with beds carrying only eurypterids and ceratiocarids, suggests that the Kokomo deposits may have approached those of some modern estuaries in which we have an alternation of marine and fresh-water deposits. The map, Fig. 8, shows the position and general extent of these late Siluric river systems.

CONCLUDING REMARKS

When the significance of the distribution and of the occurrence of the eurypterids is given its full importance, there can no longer be any doubt that the eurypterids at *no* time of their known history were normally marine organisms. We cannot conceive of marine animals presenting such localized occurrences and yet having such wide distribution as a class. The question of transit seems not to have been considered by previous authors, and yet it is one of the greatest importance. If we suppose that the eurypterids lived in the Palæozoic rivers, we have furnished them with the proper milieu for individual as well as racial development. For we must not overlook the fact that when these animals make their appearance in numbers, they are already highly differentiated. To a river dweller migrations from the headwaters of one river system to those of another are easily possible, and this is the only way by which we can account for the distribution of these organisms, unless we assume migrations along continuous shore lines which is, however, negatived by the lack of remains in the shore deposits of the period in which they most abound. Furthermore, the segregation into "pools" can be accounted for only by assuming that these "pools" were fed each by its own river system. A candid and unbiased survey of the facts presented cannot but lead to the unqualified belief in the fluviatile habits of these remarkable arthropods of the Palæozoic era of the earth's history.

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ABBREVIATIONS USED

Abhandlung d. k. k. geol. Reichsanstalt.—Abhandlung der kaiserlich-koeniglichen geologischen Reichsanstalt.

Am. Geol.—American Geologist.

Am. Jour. Sci.—American Journal of Science.

Am. Nat.—American Naturalist.

Ann. Soc. Geol. Belgique.—Annales de la Société Géologique de Belgique.

Ann. and Mag. Nat. Hist.—Annals and Magazine of Natural History.

Archiv für d. Naturk. Liv.- Ehst.- und Kurlands,—Archiv dür die Naturkunde Liv-. Ehst-. und Kurlands.

Beitr. zur. Pal. u. Geol. Oest.-Ung. u. d. Orients.—Beiträge zur Palaeontologie und Geologie Oesterreich-Ungarns und des Orients.

Brit. Ass. Adv. Sci.—British Association for the Advancement of Science.

Bull. Acad. Imp. d. Sci. St. Petersbourg.—Bulletin de l'Academie Impériale des Sciences de St.-Petersbourg.

Bull. Am. Mus. Nat. Hist.—Bulletin of the American Museum of Natural History.

Bull. Buf. Soc. Nat. Sci.—Bulletin of the Buffalo Society of Natural Sciences.

Bull. G. S. A.—Bulletin of the Geological Society of America.

Bull. Min. and Met. Soc. Am.—Bulletin of the Mining and Metallurgical Society of America.

Bull. Soc. Geol. France.—Bulletin de la Société Géologique de France.

Bull. Soc. Imp. Nat. Moscou.—Bulletin de la Société Imperiale des Naturalists de Moscou.

Can. Nat. & Geol.—Canadian Naturalist and Geologist.

Denk. d. k. Akad. d. Wiss.—Denkschriften der Kaiserlichen Akademie der Wissenschaften.

Geol. Mag.—Geological Magazine.

Jour. Geol.—Journal of Geology.

Mem. Acad. Imp. d. Sci. Saint-Petersbourg.—Memoires de l'Academie Impériale des Sciences de Saint-Petersbourg.

Mem. Geol. Surv. United Kingdom.—Memoirs of the Geological Survey of the United Kingdom.

Mem. Soc. Geol. France.—Memoires de la Société Géologique de France.

Monatsber. d. d. geol. Ges.—Monatsberichte der deutschen geologischen Gesellschaft.

Neues Jahr. Min. Geol. Pal.—Neues Jahrbuch für Mineralogie, Geologie and Paläontologie.

Proc. Am. Acad. Arts and Sci.—Proceedings of the American Academy of Arts and Sciences.

Proc. A. A. A. S.—Proceedings of the American Association for the Advancement of Science.

Proc. Am. Phil. Soc.—Proceedings of the American Philosophical Society.

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[1] Through the efficient coöperation of Miss M. F. Wilson, Librarian of the Geological Department of Columbia University, and of her assistant Miss Hepburn, I have been able to consult every one of the references in the following bibliography.

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Trans. Geol. Soc. Penn.—Transactions of the Geological Society of Pennsylvania.
Trans. G. S. Lon.—Transactions of the Geological Society of London.
Trans. N. Y. Acad. Sci.—Transactions of the New York Academy of Sciences.
Trans. Roy. Soc. Can.—Transactions of the Royal Society of Canada.
Trans. Roy. Soc. Edin.—Transactions of the Royal Society of Edinburgh.
Verh. d. Russ.-kais. min. Gesell. St. Petersburg.—Verhandlungen der russisch-kaiserlichen mineralogischen Gesellschaft zu St. Petersburg.
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